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CHEMISTRY 30

MODULE 2: PUTTING ENERGY TO WORK



**Distance
Learning**

Alberta
EDUCATION



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Chemistry 30

Module 2

Putting Energy to Work



**Distance
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Other	

Chemistry 30
 Student Module
 Module 2
 Putting Energy to Work
 Alberta Distance Learning Centre
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Welcome to Module 2!

We hope you'll enjoy your study of *Putting Energy to Work*.

Remember, to make your learning a bit easier, several videocassettes are referred to throughout the modules. Your textbook *Nelson Chemistry* will also enhance your studies.



COURSE OVERVIEW

This course contains seven modules. The module you are working in is highlighted in deeper colour. It is recommended that you work through the modules in the order given since several concepts build on each other as you progress in the course.

CHEMISTRY 30



Module 1
Exploring Energy's Mysteries



Module 2
Putting Energy to Work



Module 3
Electrochemistry – Give and Take



Module 4
The Practical Side of Redox



Module 5
Chemistry in Balance



Module 6
The Nature of Acids and Bases



Module 7
Acid-Base Applications

Contents

Module Overview	1
Evaluation	2
Section 1: Expressing Enthalpy	3
Activity 1: Standard Enthalpies – The Molar Way	4
Activity 2: Reaction Enthalpies – A Lot of Potential	8
Activity 3: Picture the Potential	14
Follow-up Activities	19
Extra Help	19
Enrichment	22
Conclusion	23
Assignment	23
Section 2: Energy Is Predictable	26
Activity 1: Hess’s Simple Solution	27
Activity 2: Hess’s Law in the Lab	32
Activity 3: Predicting ΔH°_r with ΔH°_f	37
Follow-up Activities	42
Extra Help	42
Enrichment	45
Conclusion	46
Assignment	47

MODULE

2

Contents

Continued

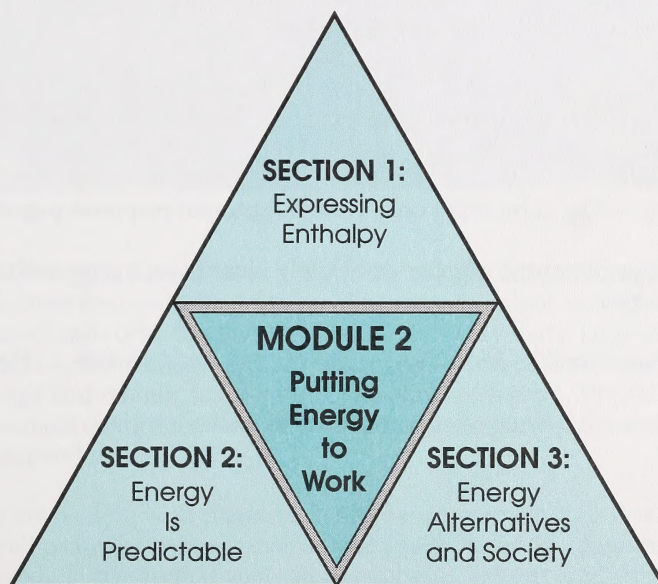
Section 3: Energy Alternatives and Society	50
Activity 1: Nuclear Energy	51
Activity 2: Energy Alternatives	56
Activity 3: Energy and Risks	63
Activity 4: The Ultimate Energy Question	74
Follow-up Activities	77
Extra Help	77
Enrichment	79
Conclusion	80
Assignment	80
Module Summary	82
Final Module Assignment	82
Appendix	87
Glossary	88
Suggested Answers	88
Article Readings	142

MODULE OVERVIEW

You have probably read newspaper articles about explosions that have accidentally occurred in coal mines or, closer to home, in someone's house. You may have seen accounts of such explosions on television. Do you know what causes these explosions? Sometimes high levels of methane or natural gas can develop naturally in coal mines, or they may develop as a result of a natural gas leak in your home. A small spark can ignite the gas, resulting in a chemical reaction involving large amounts of energy being quickly released into the surroundings.

All chemical reactions involve energy changes during the process of breaking and forming new bonds. The magnitude of the energy change involved varies in each reaction. Society uses the energy obtained through chemical changes, but the results can sometimes be devastating. In this module you will be studying about energy changes involved during chemical changes. You will learn how to calculate the heat of a reaction using several methods.

Society also uses energy that is not obtained through chemical change. Do you know of other ways of obtaining the energy needed by society besides through chemical changes? Research is constantly ongoing, looking for ways to tap alternative energy sources such as solar, wind, or nuclear sources. In this module, you will also consider some possible alternative sources of energy and their associated risks and benefits.



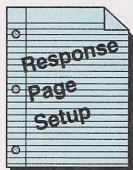
Evaluation

Your mark in this module will be determined by how well you complete the assignments at the end of each section. You must complete all assignments. In this module you are expected to complete three assignments. The mark distribution is as follows:

Section 1 Assignment	30 marks
Section 2 Assignment	30 marks
Section 3 Assignment	15 marks
Final Module Assignment	<u>25 marks</u>
TOTAL	100 marks

When doing your assignments, work slowly and carefully. If you are having difficulties, go back and review the appropriate section.

Read all parts of your assignment carefully. Plan and do your rough work on your own paper. Revise and edit your responses; then set up your final copy for submission on your own paper. Lined looseleaf is recommended. Make sure your answers are neat and organized, with wide left margins and space for teacher comments after each assignment.



When you see this icon, ideas and details are provided to help you set up and organize your answer in a certain way.

Before submitting your responses, be sure to proofread them carefully to ensure they say what you want, that they are neat and clear, and that they are complete and missing no material.

You will be submitting **only** your **assignment response pages** for evaluation.

It is important to number and clearly identify each page with this information placed at the top.

Chemistry 30 – Module 2 Section # Assignment Page # Name and ID #

SECTION

1

Expressing Enthalpy



WESTFILE INC.

What types of energy are required to build roads or railroads in mountainous areas? You might say that the mechanical energy of heavy equipment is needed to move large amounts of earth and rock. But you are more likely to say that a large part of the job would require the chemical energy from dynamite. The explosion that results from the chemical change in dynamite involves large amounts of energy. Would it be important to know how much energy is released when a certain amount of dynamite is set off? Lives might depend on it.

Whether you are dealing with chemical changes such as explosions or with reactions such as neutralization, it is often important for you to know the magnitude of the energy change involved. In this section you will learn about methods scientists have developed to measure and calculate the enthalpy change involved in a chemical reaction. You will also discover how to draw potential energy diagrams for enthalpy changes occurring during chemical reactions.

ACTIVITY

1

Standard Enthalpies – The Molar Way



When you solved for energy changes in Module 1, how did you solve for q ? for ΔH ?

1. What would your answers be to the questions posed in the preceding graphic?

Check your answers by turning to the Appendix, Section 1: Activity 1.

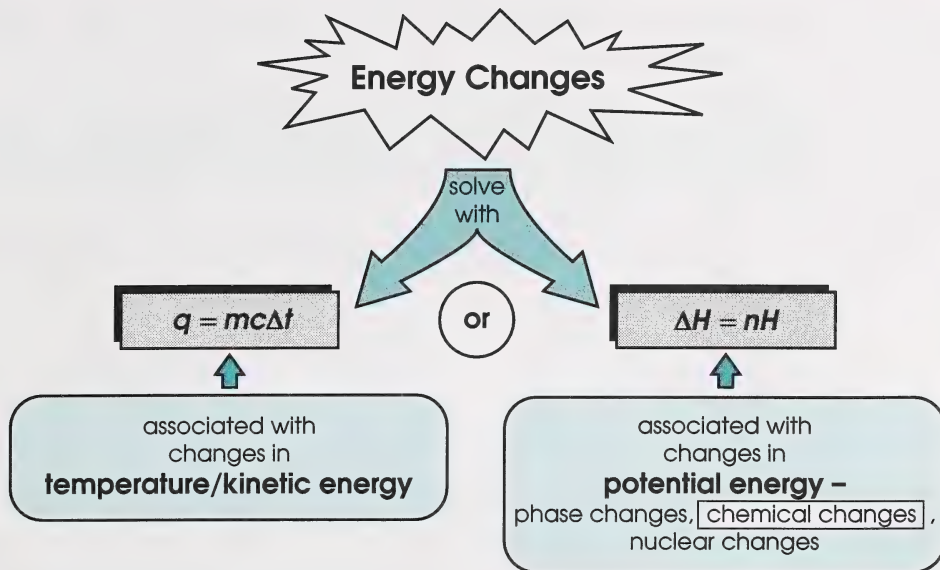
In Module 1 you learned how to use the equations referred to in the preceding question to determine the energy values for temperature (kinetic energy) changes and phase (potential energy) changes. To review these concepts answer the next three questions.

2. Complete the following table.

Quantity	Symbol	Unit
Flow of heat		
Enthalpy change		
Molar enthalpy		
Change in temperature		
Specific heat capacity		

3. What quantity of energy is required to change 10.0 g of ice at 0.0°C to water at 0.0°C?
4. How much energy is needed to raise the temperature of 2.50 L of water from room temperature (25.0°C) to 60.0°C?

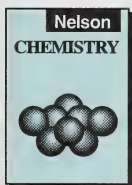
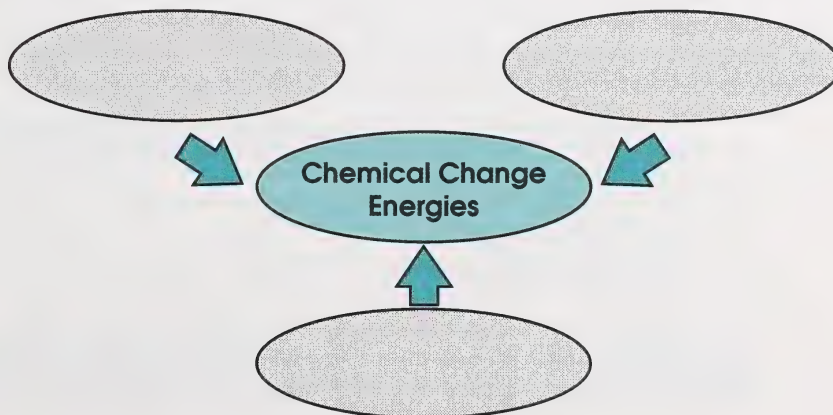
Check your answers by turning to the Appendix, Section 1: Activity 1.



You discovered in Module 1 that the energy change associated with a phase change resulted from the breaking and making of *intermolecular* bonds. Since a chemical change also involves the breaking and making of bonds (*intramolecular*), the potential energy change will be solved using $\Delta H = nH$, just as are phase change energies. You will find in general, though, that chemical change energies are larger because you are breaking and making *stronger* bonds.

To learn about the different terms used to describe energy changes for chemical reactions, read the first two paragraphs on page 315 of your textbook.

- Fill in a diagram similar to the following to illustrate the various ways of describing energy changes associated with a chemical reaction.



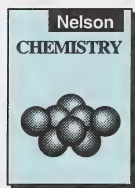
6. List the four methods by which enthalpy changes of chemical reactions can be communicated.

Check your answers by turning to the Appendix, Section 1: Activity 1.

As you work through the four methods described in the preceding question, keep in mind the following:



- *Molar enthalpy values* are symbolized by H and have the units J/mol or kJ/mol.
- *Enthalpy changes* are symbolized by ΔH and have the units J or kJ.



In the first method of describing energy changes, heat energy values are related to specific molar quantities of participants in a chemical change. To learn what is meant by the molar enthalpy of reaction in this method, read the section entitled Method 1: Molar Enthalpies of Reaction on pages 315-316 of *Nelson Chemistry*.

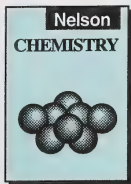
7. How are molar enthalpies measured empirically?
8. a. Explain the meaning of the following expression:



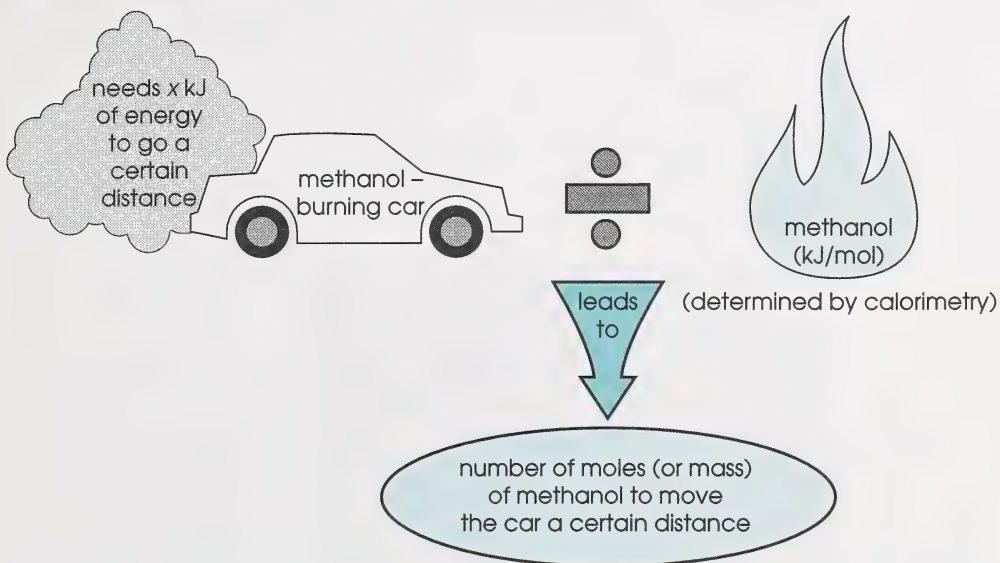
- b. Write the balanced chemical equation representing the preceding expression.
- c. Give the name used to describe this specific type of chemical reaction.
9. What does the symbol H_c° represent? Write a chemical equation which represents such a reaction.
10. Complete the following chart by explaining what each of the symbols represents.

Symbol	Explanation
H°	
H	
H_r°	

Check your answers by turning to the Appendix, Section 1: Activity 1.



The standard molar enthalpy and the balanced equation for the combustion of methanol, $\text{CH}_3\text{OH}_{(l)}$, are given to you on page 316 of *Nelson Chemistry*. Figure 11.2 on the same page refers to the technology of methanol-burning cars as an alternative fuel to gasoline. The figure also mentions that it takes twice as much methanol as gasoline to drive a certain distance. How is that value (twice) determined? What is the connection between the enthalpy of combustion of methanol and calculating the amount of methanol needed to travel a certain distance in a methanol-burning vehicle? Engineers need to consider these questions when designing a methanol-burning vehicle.



The important starting point for the preceding discussion is knowing the molar enthalpy of combustion for methanol. If you had to determine this yourself, how would you do it?

11. a. Using your knowledge of calorimetry methods from Module 1, and the knowledge you have acquired so far in this module, write a design for a simple experiment to determine the molar enthalpy of combustion for methanol.

(Hint: Methanol can be burned in a spirit lamp or burner similar to the one used for ethanol in the Section 2 Assignment of Module 1. Also, fondue burners often use methanol as fuel.)

- b. List two assumptions made in your design.

Note: The combustion of methanol will be pursued further in a later activity.

- c. Indicate, in an evidence table, the evidence you would need for the enthalpy calculation.

Science Skills	
☒	A. Initiating
☐	B. Collecting
☐	C. Organizing
☒	D. Analysing
☐	E. Synthesizing
☐	F. Evaluating

- d. Set up the calculation equation you could use to calculate the molar enthalpy of combustion for methanol.

Check your answers by turning to the Appendix, Section 1: Activity 1.

Although there are many different chemical reactions and several different methods of representing the energy changes involved, there is one thing common to **all** reactions – they all involve changes in enthalpy.

ACTIVITY

2 Reaction Enthalpies – A Lot of Potential



NASA

Did you know that hydrogen has been called the fuel of the twenty-first century? Can you think of any reasons why? One of the reasons is that when hydrogen is burned as a fuel, it releases large amounts of thermal energy.

Hydrogen has long been used as a fuel in the space programs. Now engineers and scientists are proposing hydrogen as a fuel to power motor vehicles, power plants, and other industrial technologies. Other attractions for using hydrogen include its availability (it can be produced from water) and the fact that it is clean-burning (it produces only heat and water). Hydrogen combustion would have minimal impact on the environment.

1. Write a balanced equation, using whole numbers, showing the combustion of hydrogen gas.

Check your answer by turning to the Appendix, Section 1: Activity 2.

But how do you calculate the amount of energy change involved in this hydrogen combustion reaction? To answer this question, read the section titled Method 2: Enthalpy Changes, ΔH on pages 316-317 of your textbook.

2. What two things are required to calculate the enthalpy change of a reaction?
3. How is the enthalpy change for a reaction reported once it has been calculated?
4. How do you know what sign, + or -, to attach to the enthalpy value?
5. a. What unit does the enthalpy value have when it is associated with a chemical equation?
b. How is this different from the unit of a molar enthalpy value?
6. Using the balanced equation for the combustion of hydrogen gas (from question 1) and the standard molar enthalpy of formation of water vapour as -241.8 kJ/mol , calculate the enthalpy change for the combustion of hydrogen gas.

Check your answers by turning to the Appendix, Section 1: Activity 2.

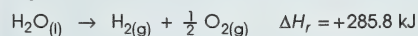
Molar Enthalpies

e.g.,

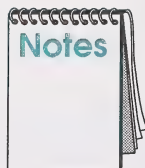
$$H^\circ_f(\text{CO}_2) = -393.5 \text{ kJ/mol}$$

Enthalpy Changes of Reactions

e.g.,



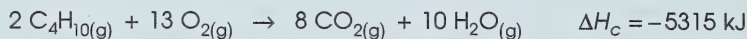
**Describing
Enthalpy
Changes**



- Molar enthalpy has the units **kJ/mol** and is symbolized in your textbook and this course by H . As mentioned in Module 1, other references may use ΔH symbols for this value, but the units are the same.
- Enthalpy changes associated with equations only have the unit **kJ** because the moles are indicated by the equation.

Example

You are given the following information for the combustion of butane (for example, in a portable hair curler):



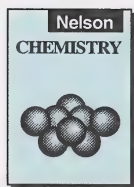
All of the following descriptions would apply with respect to this reaction:

$$\frac{5315 \text{ kJ released}}{2 \text{ mol C}_4\text{H}_{10} \text{ reacted}} \\ (\text{or } -2658 \text{ kJ/mol C}_4\text{H}_{10})$$

$$\frac{5315 \text{ kJ released}}{13 \text{ mol O}_2 \text{ reacted}} \\ (\text{or } -409 \text{ kJ/mol O}_2)$$

$$\frac{5315 \text{ kJ released}}{8 \text{ mol CO}_2 \text{ produced}} \\ (\text{or } -664 \text{ kJ/mol CO}_2)$$

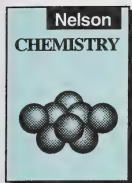
$$\frac{5315 \text{ kJ released}}{10 \text{ mol H}_2\text{O produced}} \\ (\text{or } -532 \text{ kJ/mol H}_2\text{O})$$



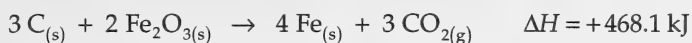
As you have already seen, standard molar enthalpy values can be used, along with an amount (moles) of substance reacted or produced, to find the enthalpy change of a reaction. Standard molar enthalpy values are often supplied in a data table in textbooks or reference books. An example is the Standard Molar Enthalpies of Formation table that can be found on page 551 of your textbook. You will often use this table throughout the remainder of this module.

Another source of this information is the Chemistry Data Booklet found at the end of the Appendix in Module 7 of this course. Because the data booklet is almost identical to the one you will use when you write your Chemistry 30 diploma examination, being familiar with the data booklet may be to your advantage.

For more practice in solving problems involving enthalpy changes of reactions, answer the following questions.



7. a. Using the value for the H°_f of $\text{SO}_{2(g)}$ from page 551 of your textbook, write the standard molar enthalpy of formation equation for $\text{SO}_{2(g)}$ with its associated enthalpy change value. (Remember, sulphur is $\text{S}_{8(s)}$.)
- b. Determine the enthalpy change for the formation of 1.50 mol of $\text{SO}_{2(g)}$.
- c. Using the same equation as in 7.a., determine the enthalpy change for the combustion for 3.20 mol of sulphur.
8. a. Determine the enthalpy change if 25.6 g of solid iron is produced during an industrial process according to the following chemical equation:



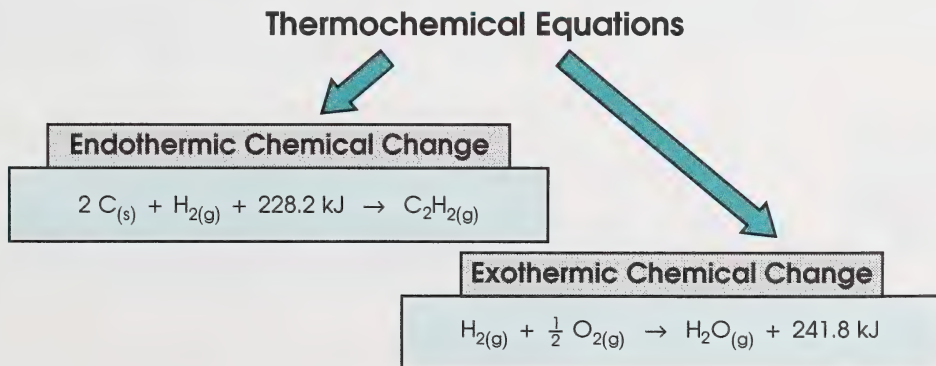
- b. Is the process described in 8.a. exothermic or endothermic? Explain.
9. If the combustion of 1.28 mol of benzene, $\text{C}_6\text{H}_{6(l)}$, produces an enthalpy change of -8027 kJ , what is the enthalpy change for this combustion reaction as balanced in the following equation?



Check your answers by turning to the Appendix, Section 1: Activity 2.

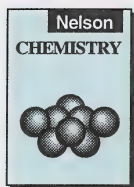
You have seen how ΔH notation is used to show an enthalpy change of a reaction. How do you think you could include the value for an enthalpy change inside the chemical equation itself? A third method used to communicate enthalpy change of a reaction involves the use of **thermochemical equations**. The following diagram illustrates how to write thermochemical equations.

thermochemical equations – chemical equations which show an energy change as part of the equation



As you can see in the preceding diagram, thermochemical equations include the energy change as a part of the equation. The following guidelines will help you in writing such equations:

- The stoichiometric coefficients refer to the moles of each substance.
- Reversing the equation does not change the magnitude of the enthalpy change.
- If the equation is changed by a factor on both sides, then the ΔH or enthalpy value is also changed by the same amount.

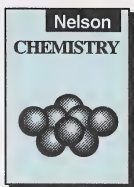
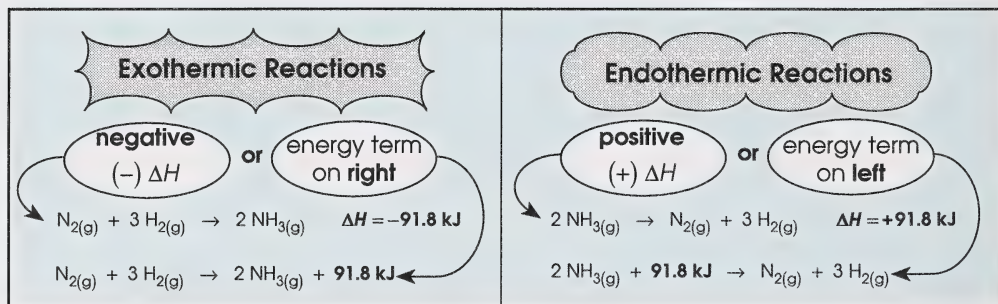


Read the section titled Method 3: Energy Terms in Balanced Equations on page 317 of *Nelson Chemistry* to learn more about this method. Answer the following questions to check your understanding.

10. Use the chemical equation which follows to answer this question.



- Write a thermochemical equation for this reaction.
- Write a thermochemical equation for the reverse reaction.
- Calculate the molar enthalpy for the combustion of acetylene, $\text{C}_2\text{H}_{2(g)}$.



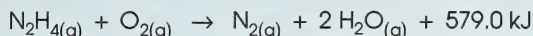
11. For more practice in applying the various methods you have discovered for describing enthalpy changes, answer textbook questions 1-5 on pages 319-320 in *Nelson Chemistry*.

Check your answers by turning to the Appendix, Section 1: Activity 2.

You saw in an earlier question (question 8) in this activity that not only mole quantities, but mass quantities as well, can be related to enthalpy changes. The following example illustrates this relationship with a thermochemical equation.

Example

The enthalpy change from the combustion of hydrazine, N_2H_4 , is sometimes used to power rockets into space, according to the following equation:



What mass of hydrazine would be needed to generate an enthalpy change of $2.35 \times 10^8 \text{ kJ}$?

Step 1

Calculate the molar enthalpy value for the combustion of hydrazine, $\text{N}_2\text{H}_{4(\text{g})}$.

$$\begin{aligned} H_c &= \frac{\Delta H_c}{n} \\ &= \frac{-579.0 \text{ kJ}}{1 \text{ mol N}_2\text{H}_4} \quad \leftarrow \text{Remember, an enthalpy value on the right side of the equation means that the } \Delta H \text{ value is negative (-) and the reaction is exothermic.} \\ &= -579.0 \text{ kJ/mol N}_2\text{H}_4 \end{aligned}$$

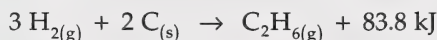
Step 2

Calculate the mass of $\text{N}_2\text{H}_{4(\text{g})}$ required using the given energy value, the answer from Step 1, and the molar mass of $\text{N}_2\text{H}_{4(\text{g})}$.

$$\begin{aligned} m_{(\text{N}_2\text{H}_4)} &= 2.35 \times 10^8 \text{ kJ} \times \frac{1 \text{ mol N}_2\text{H}_4}{579.0 \text{ kJ}} \times \frac{32.06 \text{ g}}{1 \text{ mol N}_2\text{H}_4} \\ &= 1.30 \times 10^7 \text{ g} \\ &= 13.0 \text{ Mg (tonnes)} \end{aligned}$$

Note that, for finding the mass, the negative sign was not needed ($\times 579.0 \text{ kJ}$). The sign merely tells you that heat is lost.

12. Use the following reaction equation to answer this question.



- Calculate the enthalpy change (heat of reaction) for the *decomposition* of 62.3 g of ethane, C_2H_6 .
- What is the name that can be used to describe the type of reaction equation that is given in this question?

13. The standard molar enthalpy or heat of formation for magnesium oxide is -601.6 kJ/mol .
- Write a thermochemical equation to represent this change.
 - Calculate the energy change involved for the formation of 5.00 g of magnesium oxide.

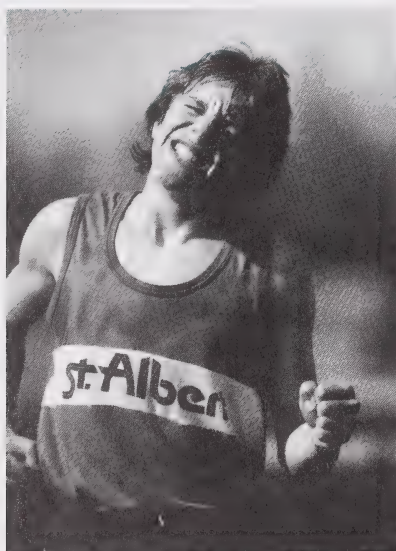
Check your answers by turning to the Appendix, Section 1: Activity 2.

You have seen a variety of ways of expressing the enthalpy or heat change associated with chemical reactions: molar enthalpies, enthalpy changes of reactions, thermochemical equations. What is next?

ACTIVITY

3

Picture the Potential



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NUTRITION INFORMATION	
PER 35g SERVING	
ENERGY	133 CALORIES
	560 kJ
•Protein	3.7 g
•Fat	0.7 g
•Carbohydrate	27.9 g
Sugars	1.7 g
Starch	21.6 g
Dietary Fibre	4.6 g
•Sodium	135 mg
•Potassium	190 mg
PERCENTAGE OF RECOMMENDED INTAKE	
.....	53%
.....	7.3%
.....	33%



How long do you think this athlete could run using the energy released by one serving of this cereal? How could you represent the enthalpy change associated with the reaction of this cereal in the athlete's body? You have already seen several methods which could be used, but how could the energy released be represented on a potential energy diagram?

Potential energy diagrams are not new to you. In Module 1 you learned about using potential energy diagrams to represent phase changes. Such diagrams can also be used to represent enthalpy changes taking place during chemical changes. Since the “combustion” (more correctly referred to as metabolism) of cereal in the body is a chemical reaction, potential energy diagrams can be used to represent this energy change as well.

1. The metabolism of the cereal in the athlete’s body would involve a reaction with oxygen to produce carbon dioxide and liquid water. Using the information from the preceding graphic, and your knowledge from Module 1, draw a potential energy diagram which would represent the metabolism of the cereal.

Check your answer by turning to the Appendix, Section 1: Activity 3.

Potential energy diagrams are another method that can be used to represent an energy change during a chemical reaction.

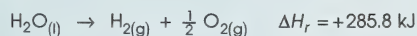
Molar Enthalpies

e.g.,

$$H_f^\circ(\text{CO}_2) = -393.5 \text{ kJ/mol}$$

Enthalpy Changes of Reactions

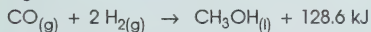
e.g.,



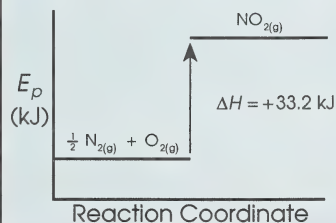
Describing Enthalpy Changes

Thermochemical Equations

e.g.,



Potential Energy Diagrams



For further instruction on potential energy diagrams associated with chemical reactions, read the section titled Method 4: Potential Energy Diagrams on pages 317-318 of your textbook. Pay special attention to the summary on the bottom of page 318.

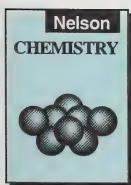


Figure 2.1 illustrates how hydrogen chloride gas can be formed from its elements. Take note of the relative positions of the products and reactants.

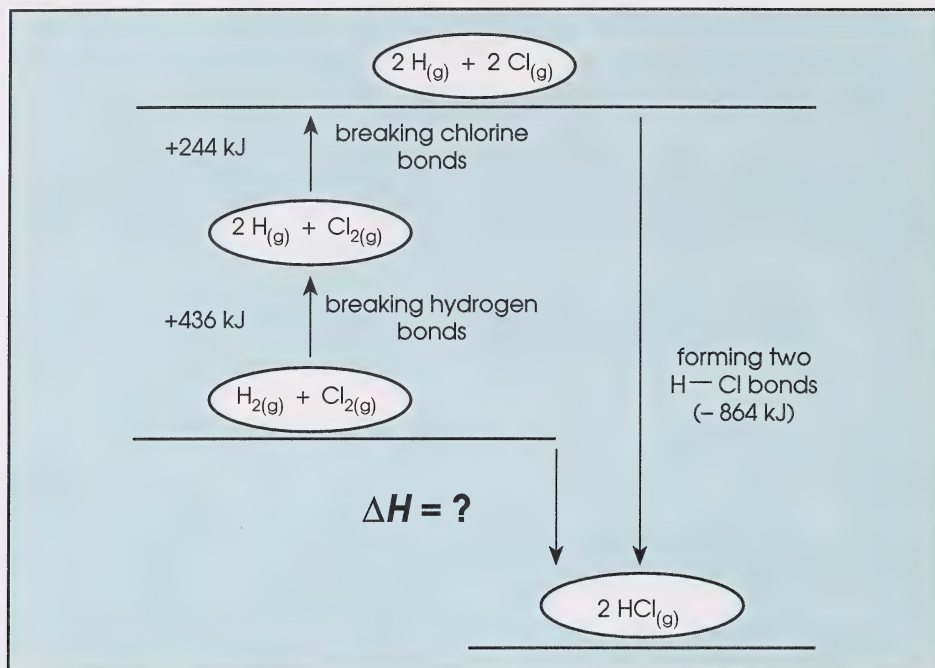
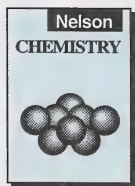
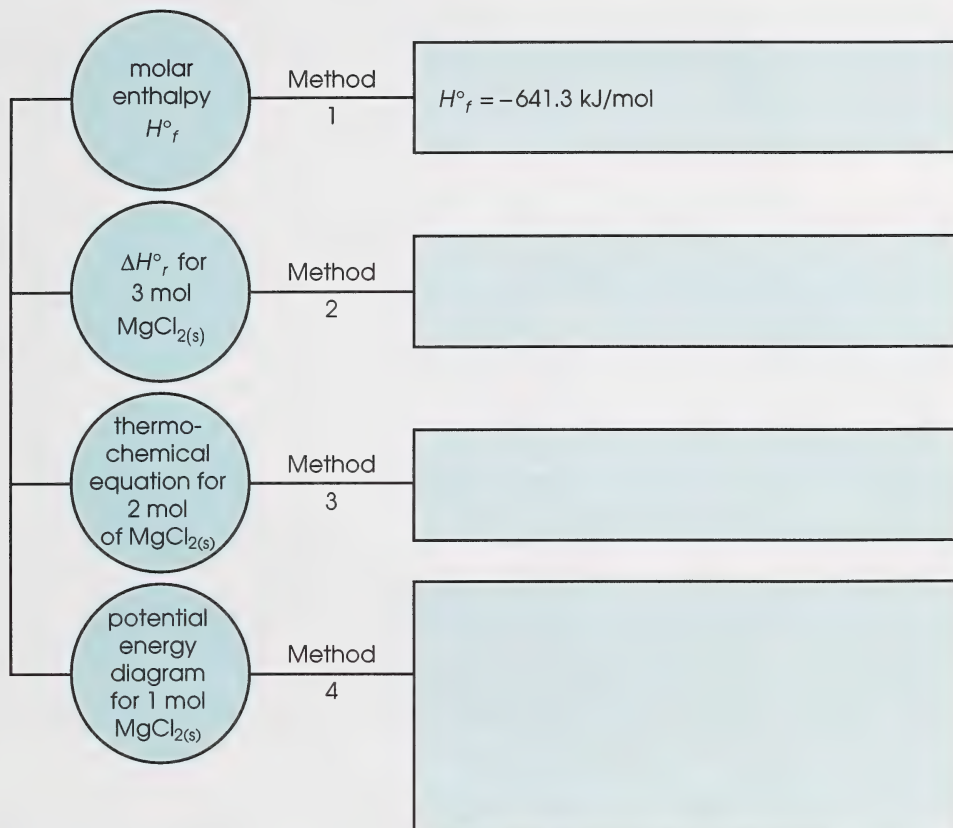


FIGURE 2.1: The Formation of Hydrogen Chloride Gas

2. a. Use the information in Figure 2.1 to draw and label a potential energy diagram that would represent the net chemical change from start to end.
 - b. From your diagram, what would be the molar heat of formation of $\text{HCl}_{(\text{g})}$?
 - c. Draw and label a potential energy diagram for the reverse reaction – the decomposition of 1 mol of $\text{HCl}_{(\text{g})}$.
 - d. For each of the following structural changes, indicate whether the energy change is exothermic or endothermic.
 - i. forming bonds
 - ii. breaking bonds
3. Answer textbook question 6 given on page 320 of *Nelson Chemistry*.



4. Reproduce a diagram (of an appropriate size) similar to the following for showing the reaction between the elements magnesium and chlorine in their natural states to form magnesium chloride. Fill in the missing information. Method 1 is done for you. Consider the molar quantities given as being exact numbers.

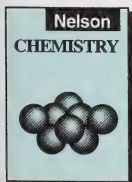


cellular respiration – the controlled oxidation of carbohydrates to release energy in living cells

photosynthesis – the formation of carbohydrates by chlorophyll-containing plants exposed to sunlight

Check your answers by turning to the Appendix, Section 1: Activity 3.

Earlier in this activity, the combustion of cereal in your body was mentioned as a means of obtaining food energy. The **cellular respiration** of the carbohydrates contained in cereal is much more complicated than just the “combustion” of cereal. What is the compound extracted from the cereal by your body that is actually “burned” to produce energy? The processes of cellular respiration and the reverse reaction which occurs in **photosynthesis** are illustrated by potential energy diagrams on page 319 of your textbook. Study the diagrams; then answer the following questions to check your understanding.



- What is the difference between the two potential energy diagrams for cellular respiration and photosynthesis?
- Calculate the enthalpy changes involved for 3.5 g of glucose reacting in cellular respiration and photosynthesis, according to the reactions given in your textbook.

Check your answers by turning to the Appendix, Section 1: Activity 3.

Can you think of another advantage of a potential energy diagram? Can you tell by looking at a potential energy diagram or at a chemical equation with associated enthalpy change which has more stored (potential) energy, the reactants or products? Yes. As shown in the potential energy diagram in Figure 2.2, an endothermic reaction has its reactants at a lower level than its products. This shows you that in endothermic reactions, the reactants have **less** stored energy than the products.

This information about the relative amounts of stored energy can often be useful in predicting whether or not a reaction will occur. Nature tends to, in terms of energy, favour the side of a reaction with less stored energy because the substances on this side are generally more stable. That implies that an endothermic reaction would have a hard time operating spontaneously because the natural tendency is to remain as the more stable (energy-wise) reactants. This is usually the case because most endothermic reactions require a constant input of energy to react. Figure 2.2 also shows you that in a thermochemical equation, the side containing the energy term has less stored energy in the substances than the other side.

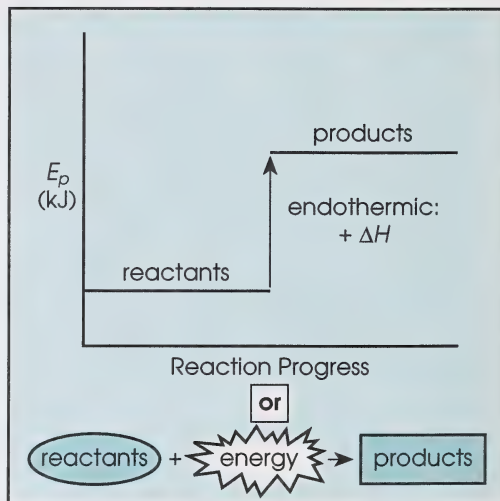
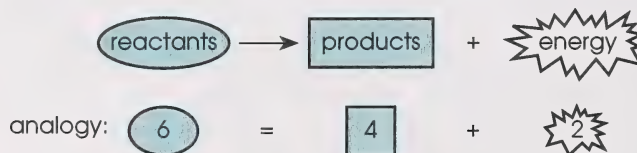


FIGURE 2.2: Stored Energy in Endothermic Reactions

The following graphic illustrates an exothermic reaction equation.

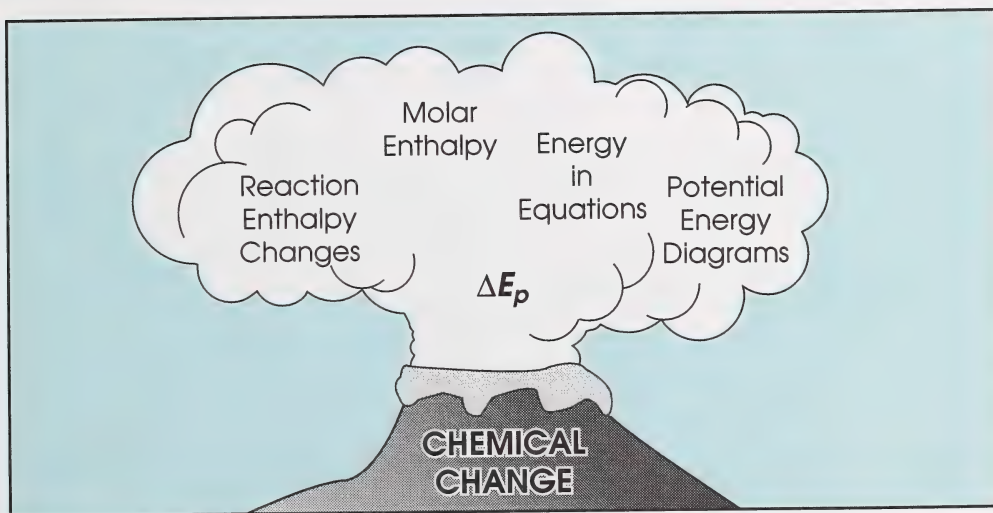


Notice that, since both sides must be equal (in terms of energy) in the exothermic thermochemical equation, the products must have less stored energy than the reactants so that energy is conserved.

7. State a generalization for both exothermic and endothermic chemical reactions in terms of the relative amount of stored potential energy in the reactants versus the products.

Check your answers by turning to the Appendix, Section 1: Activity 3.

A lot of information can be extracted from a chemical equation or potential energy diagram with their associated enthalpy changes. You have now seen a variety of ways of presenting this information.



Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

Review the main concepts discussed in this section by completing the following questions.

1. List the four methods of communicating enthalpy changes for a chemical reaction.

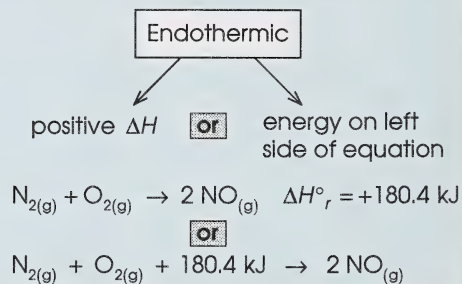
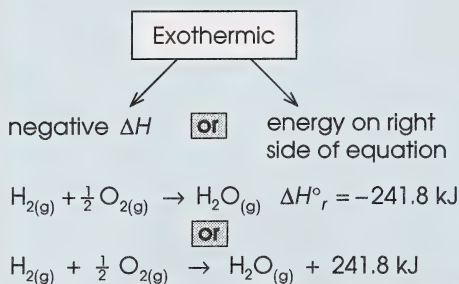
Points to Remember:

- Molar enthalpy values in *Nelson Chemistry* and in this course have the symbol H , usually with a subscript (other references may use ΔH symbols). These values have the units kJ/mol .

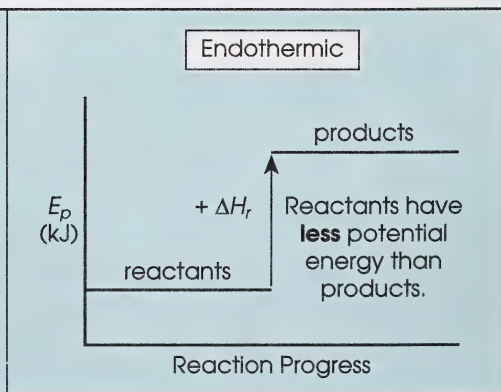
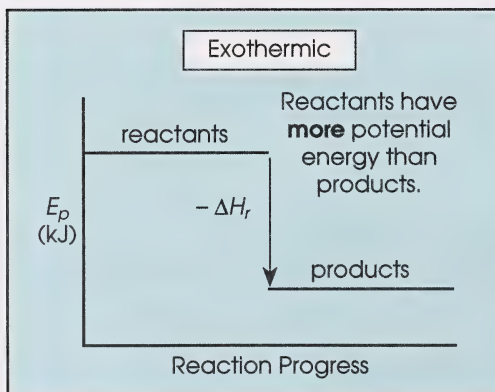
Example

Standard molar enthalpy (heat) of formation of $\text{CH}_{4(g)}$: $H^\circ_f = -74.4 \text{ kJ/mol}$

- Enthalpy changes associated with chemical equations, either with the ΔH notation or written within the equation (thermochemical equation), have the units kJ . The amount (moles) of each substance is indicated by the coefficients in the balanced equation.

Example

- Potential Energy Diagrams



2. Write a balanced equation, including the ΔH_r , for this information:

The enthalpy change for the formation of 2 mol of lead(II) oxide from its elements is -438.0 kJ .

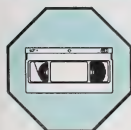
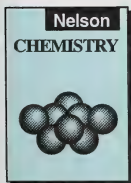
3. The standard molar enthalpy for the formation of carbon disulphide, $\text{CS}_{2(l)}$, is $+89.0 \text{ kJ/mol}$.
- Write a thermochemical equation (energy term is contained within the equation) that represents the formation of carbon disulphide.
 - Draw a potential energy diagram for the reaction.
4. Identify the following changes as endothermic or exothermic.
- $\text{Fe}_3\text{O}_{4(s)} + \text{CO}_{(g)} + 38 \text{ kJ} \rightarrow 3 \text{FeO}_{(s)} + \text{CO}_{2(g)}$
 - $4 \text{NH}_{3(g)} + 5 \text{O}_{2(g)} \rightarrow 4 \text{NO}_{(g)} + 6 \text{H}_2\text{O}_{(l)} + 1170 \text{ kJ}$
 - $\text{H}_2\text{O}_{(l)} + 56.2 \text{ kJ} \rightarrow \text{H}^+_{(aq)} + \text{OH}^-_{(aq)}$
 - $226 \text{ kJ} + 2 \text{C}_{(\text{graphite})} + 2 \text{H}_{2(g)} \rightarrow \text{C}_2\text{H}_{2(g)}$
5. Given reaction: $2 \text{NO}_{(g)} + \text{O}_{2(g)} \rightarrow \text{N}_2\text{O}_{4(g)}$

If the molar enthalpy for $\text{N}_2\text{O}_{4(g)}$ in the given reaction is -322 kJ , what is the enthalpy change for 1.5 mol of $\text{N}_2\text{O}_{4(g)}$?

Check your answers by turning to the Appendix, Section 1: Extra Help.

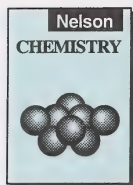
If you would like further practice in working with the concepts presented in this section, answer any of questions 2, 3, 5-7, and 12-18 on pages 340-341 of your textbook. The answers to these questions can be found on pages 513-514 of *Nelson Chemistry*.

If you have access to the video titled *Chemical Energy*, watch the first five minutes of the video. The parts titled Energy in Food, Photosynthesis, and Gas Fuels review some practical applications of the concepts you have studied in this section.



Enrichment

Do any **one** of the following questions.



1. There are often times when the enthalpy change of a chemical reaction is required, but there is no information such as calorimetry data to allow you to calculate the enthalpy change. One option you have for estimating the enthalpy change of a reaction is using bond energies. Research the term *bond energy* and the associated method of solving enthalpy changes. Then, use the following information to calculate the enthalpy change for the formation of two moles of ammonia from its elements. Compare this estimated value to double the value for the standard molar enthalpy of formation of ammonia found on page 551 of your textbook.

AVERAGE BOND ENERGIES AT 298 K

Bond	Bond Energy (kJ/mol)
H—H	432
N≡N	941
N—H	391

2. As mentioned earlier in this section, hydrogen gas as a fuel is being explored more and more as an alternative to using fossil fuels. The Hydrogen Research and Technology Branch, Alberta Energy, has stepped up its research for the economical production of hydrogen gas. Talk to a person in The Hydrogen Research and Technology Branch about some advantages and disadvantages of using hydrogen as a fuel and the different areas in which research is being done in this field. Write a report to summarize your discussion.
3. Ways of becoming more energy-efficient are more important than ever today. Society's energy demands and the effect of energy producers on the environment are creating a growing need for more energy-conscious consumers.

Now that you have some background in the concepts of energy heat transfer and calorimetry, you should be able to devise some methods for conserving energy.

Get together with family or friends and generate a list of different ways you can become more energy-efficient around the home. If you need extra help in completing your list, possible sources you can contact are the Energy Efficiency Branch, Department of Energy, Government of Alberta; your gas company; or your electrical company.

Check your answers by turning to the Appendix, Section 1: Enrichment.

Conclusion

In this section you have studied the different methods used to communicate enthalpy changes for chemical reactions. Molar enthalpies and enthalpy changes during reactions provide you with an important means of tracking heat transfers during chemical changes. Calorimetry has been reinforced as a valuable tool in discovering the magnitude of energy change and the exothermic or endothermic nature of chemical reactions. In the next section you will discover some different methods used to calculate the magnitude of energy changes during such reactions.

30

Section 1 Assignment: Expressing Enthalpy

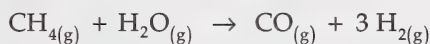
Review the Evaluation information found in the introductory pages of this module.

It is important to number and clearly identify each page with the following information at the top:

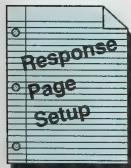
Chemistry 30 – Module 2 Section 1 Assignment Page # Name and ID#

Be sure to write legibly. Leave a wide left margin and number all of your pages.

1. The most common method for the production of hydrogen gas is through the reaction of steam with hydrocarbons such as methane gas. The equation for the reaction involved is as follows:



- a. When one mole of methane reacts according to the given equation, 206.1 kJ of energy is absorbed. What is the change in enthalpy for 1.00 kg of methane reacting? Show all required work. (4 marks)
 - b. Using the preceding given information, write a thermochemical equation for one mole of methane in the given reaction. Also write an equation with ΔH_r notation for the reverse reaction for one mole of methane. (2 marks)
 - c. Draw a labelled potential energy diagram for one mole of methane reacting in the given equation. Your potential energy diagram should be labelled and about 5 cm-7 cm high. (3 marks)
2. Lattice energy is the energy required to completely separate one mole of a solid ionic compound into gaseous ions. The substances X and Y are two ionic compounds and X has a higher lattice energy. Which of the two substances, X or Y, is most likely more stable? Explain your answer. (2 marks)



Science Skills

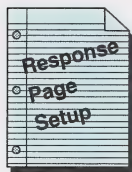
- ☐ A. Initiating
☐ B. Collecting
☐ C. Organizing
☒ D. Analysing
☐ E. Synthesizing
☐ F. Evaluating

3. You are given the following data:

COMBUSTION DATA OF VARIOUS ALCOHOLS	
Alcohol	Energy per 1.00 g Burned
methanol, $\text{CH}_3\text{OH}_{(l)}$	-22.6 kJ
ethanol, $\text{C}_2\text{H}_5\text{OH}_{(l)}$	-29.7 kJ
propanol, $\text{C}_3\text{H}_7\text{OH}_{(l)}$	-33.4 kJ

- a. Calculate the molar enthalpy of combustion for each alcohol given. (6 marks)
- b. The molar enthalpy of combustion varies directly with the size of the alcohol molecules. Plot a graph of molar enthalpy of combustion versus the number of carbon atoms and predict the molar enthalpy of combustion for butanol ($\text{C}_4\text{H}_9\text{OH}_{(l)}$).

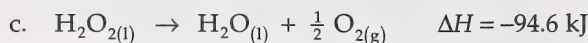
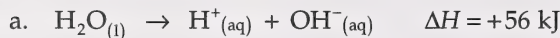
Use your calculated enthalpy values from 3.a. (rounded to the nearest kilojoule). Use the number of carbon atoms as the manipulated variable. Use graph paper to plot the graph. (4 marks)



Reproduce the science skills assessment box after your response to this question. Remember to indicate your evaluation of your skill level for each identified science skill. Leave a space for the teacher assessment.

Self: A.	☐	B.	☐	C.	☐	D.	☐	E.	☐	F.	☐
Teacher: A.	☐	B.	☐	C.	☐	D.	☐	E.	☐	F.	☐

4. Identify each of the following changes as endothermic or exothermic. (4 marks)



5. A student designed a calorimetric experiment to determine the molar heat of combustion of paraffin, $C_{25}H_{52}$, in a candle. After performing the experiment, the student recorded these data:

mass of $Al_{(s)}$ calorimeter	=	16.0 g
mass of water and calorimeter	=	410.0 g
initial temperature of water	=	20.0°C
final temperature of water	=	35.5°C
initial mass of candle	=	25.7 g
final mass of candle	=	23.5 g

Based on the data given, calculate the molar heat (enthalpy) of combustion of paraffin. Assume that only the calorimeter water absorbs heat. For full marks, your answer must show all pertinent formulas and calculations. **(5 marks)**

SECTION

2

Energy Is Predictable



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Variety is the spice of life! Have you ever heard that saying? Even if you haven't, you can probably identify with its meaning. There are many ways of doing things, which is something you have probably discovered in your life so far – it makes life interesting! Take skating, for instance. How did you learn how to skate (if you do skate)? Did you start out by holding onto a chair and pushing it along in front of you? Did you learn by holding on to someone else until you were comfortable standing on your own? Whichever way you used, you did learn to skate.

Finding energy values for chemical changes can often turn out the same way. There is usually more than one way to find the enthalpy or heat change for a chemical reaction. One way may be easier, another way may be longer, but the important thing is, each ends up with the same correct answer.

In this section, you will study two different ways to find the heat change for a chemical reaction. One method uses the process of adding equations to find heat values, in theory and in the lab; another uses heats of formation to calculate enthalpy changes.

ACTIVITY

1

Hess's Simple Solution

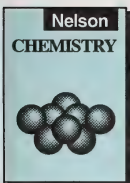
Suppose that you and a friend decide to take a holiday by travelling from Edmonton to Calgary. Your friend decides to take the more direct route – on the main four-lane highway. You decide to take the more scenic route through Jasper, Banff, then on to Calgary. You may take longer and travel a harder route but, in the end, you both end up in the same place – Calgary.

1. Satisfy yourself, with the following information, that you end up changing the same amount in elevation overall whether you go the direct route from Edmonton to Calgary, or you take the scenic route.

Elevations:

Banff – 1387 m
Calgary – 1048 m

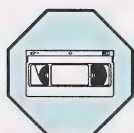
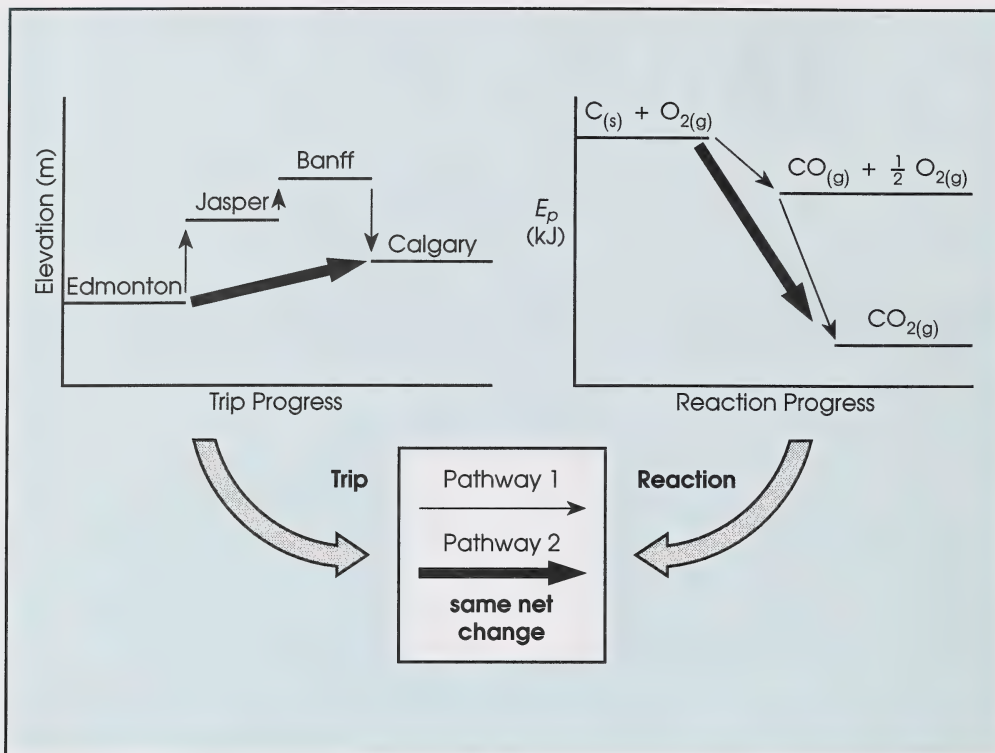
Edmonton – 665 m
Jasper – 1061 m



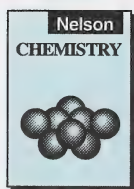
Just as there are different routes you can take to go to Calgary from Edmonton, there are different routes that can be taken to produce a given set of products in chemical reactions. The enthalpy change between the starting reactants and the end products in a chemical reaction is independent of the pathway or the number of steps it takes to get from start to end. As an introduction to this concept, read the paragraph at the bottom of page 320 and the top of page 321 of your textbook.

2. Why have chemists devised several methods for predicting enthalpy changes for chemical reactions, rather than determining the values experimentally?
3. What is the principle upon which all of these predicting methods are based?
4. Explain how the same principle applies to enthalpy changes.

Check your answers by turning to the Appendix, Section 2: Activity 1.



If you have access to the video titled *Chemical Energy*, view the sections Gaseous Fuels and Enthalpy. These sections will show you a practical application of the preceding principles.



The video *Chemical Energy* gives you a practical example of Hess's law. This same example is discussed in your textbook, along with a description of Hess's law, on pages 321-322, up to the end of the summary. Read these pages carefully, paying attention to the margin notes and the summary information.

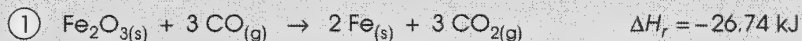
5. State Hess's law of heat summation.
6. What two rules, already familiar to you, does Hess's law use when predicting the enthalpy change of a chemical reaction?
7. In the steps you follow to determine the enthalpy (heat) of reaction using Hess's law, what two things do you do once you have correctly manipulated all the information equations?

Check your answers by turning to the Appendix, Section 2: Activity 1.

The following is an example of how to use Hess's law.

Example

- a. Calculate the enthalpy change of the reaction $2 \text{Fe}_{(s)} + \frac{3}{2} \text{O}_{2(g)} \rightarrow \text{Fe}_2\text{O}_{3(s)}$ using the following information equations:



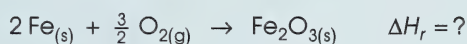
- b. Find the molar enthalpy of reaction for $\text{Fe}_{(s)}$.

- a. The enthalpy change of the reaction can be found as follows:

Step 1

Write the net equation.

The net equation required is



Focus on the following:

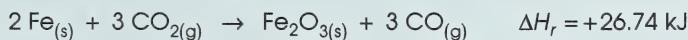
- What reactants and products are required?
- How much of each substance is required?
- Which substances in the information or given equations need to cancel?

These three points determine how you will manipulate the given information equations.

Step 2

Manipulate the given equations.

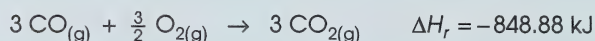
- Since $2 \text{Fe}_{(s)}$ is required as a reactant, given Equation $\textcircled{1}$ needs to be reversed, giving



↑
Don't forget the heat value!

This manipulated Equation $\textcircled{1}$ also gives you $\text{Fe}_2\text{O}_{3(s)}$ on the correct side and in the correct amount.

- Given Equation (2) is the source of $O_{2(g)}$ you need. The $O_{2(g)}$ is on the correct side in Equation (2), but not in the correct amount. Therefore, given Equation (2) is multiplied by 3 to give the correct amount, giving



Remember, **every term** is multiplied by 3, including the ΔH_r .

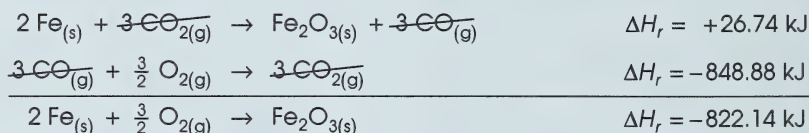
This second equation also allows the unwanted substances from Equations (1) and (2) ($3 CO_{(g)}$ and $3 CO_{2(g)}$) to cancel.

Step 3

Cancel like terms and add reactants and products.

Step 4

Add enthalpies.

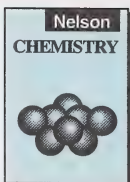


The enthalpy change of the reaction is -822.14 kJ .

- b. In this example, the molar enthalpy of reaction for $Fe_{(s)}$ is found as follows:

$$\begin{aligned}
 H_r &= \frac{\Delta H_r}{n} \\
 &= \frac{-822.14 \text{ kJ}}{2 \text{ mol Fe}} \\
 &= -411.07 \text{ kJ/mol Fe}
 \end{aligned}$$

The molar enthalpy of reaction for $Fe_{(s)}$ is -411.07 kJ/mol .

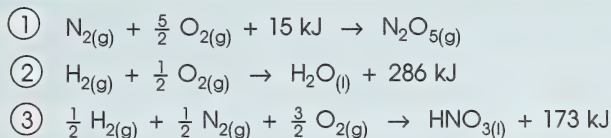


If you wish another example to clarify how to use Hess's law, study the example given on pages 322-323 in your textbook.

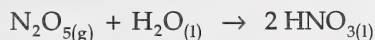
Practise using Hess's law to predict the enthalpy change of a chemical reaction by doing the following questions.

8. Do textbook questions 7-10 on pages 323-324 of *Nelson Chemistry*.

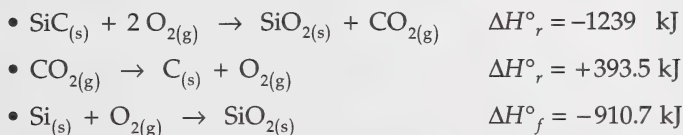
9. Use the following as information equations for this question.



From the given equations, predict the ΔH_r and draw a potential energy diagram for the following reaction:

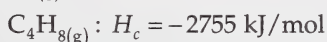
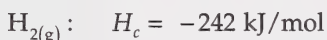
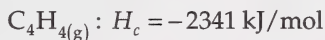


10. Use the following equations for this question:



What is the predicted ΔH°_f value for $\text{SiC}_{(\text{s})}$?

11. The H_c values for the combustion of three compounds are given as follows:



Determine the ΔH_r for $\text{C}_4\text{H}_{4(\text{g})} + 2 \text{H}_{2(\text{g})} \rightarrow \text{C}_4\text{H}_{8(\text{g})}$ from the information given.

Check your answers by turning to the Appendix, Section 2: Activity 1.

Calorimetry is not a practical tool to measure the enthalpy changes involved in many chemical changes. Can you think of one such reaction? Corrosion of metals is a slow process and therefore calorimetry is not an appropriate method to measure this enthalpy change. Hess's law can be used in such cases if the enthalpy changes for the intermediate steps are known. In the next activity you will use empirical evidence to test this law.

ACTIVITY

2

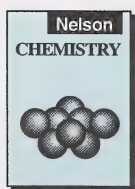
Hess's Law in the Lab



WESTFILE INC.

How do farmers grow full crops year after year to meet the continuing needs of society? Much of the credit should go to their farm management techniques. Some of the credit, though, must go to the use of fertilizers of various types. Did you know that ammonia is one of the major components of the fertilizer used by many farmers? Hydrogen gas and nitrogen gas are combined to produce the ammonia, thereby playing an important part in the production of ammonia-based fertilizers.

There are several industrial processes used to manufacture hydrogen gas (for such things as producing ammonia). One such method involves reacting steam with methane.



Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Lab Exercise 11A: Analysis Using Hess's Law

- To see how Hess's law can be applied to determine the enthalpy change for the formation of hydrogen gas from methane (natural gas) and steam, complete one possible analysis of Lab Exercise 11A on page 324 of *Nelson Chemistry*. Please note that, for any one analysis, not all the given information equations are needed. There are several possible combinations that can be used. Pay special attention to the applied science skill.

Check your answer by turning to the Appendix, Section 2: Activity 2.

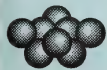
DID YOU KNOW?

Alberta industries produce 55% of all the hydrogen gas in Canada.

The combustion of hydrocarbons has wide application in industry. Can you think of one method which can be used to determine enthalpy changes for these reactions? Calorimetry is one technique that can be used, but how can you verify the experimental evidence from calorimetry? One way is to apply Hess's law.

You can also do the reverse. Hess's law can be verified by experimental evidence using calorimetry techniques. To prepare you for doing your own investigation to test Hess's law and also to verify the theoretical prediction for the enthalpy change of a reaction with experimental evidence, do Lab Exercise 11B on page 325 of your textbook. Do the following questions as the prediction, analysis, and evaluation for the exercise. Pay special attention to the applied science skills.

Nelson
CHEMISTRY

**Science Skills**

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☐ E. Synthesizing
- ☒ F. Evaluating

Lab Exercise 11B: Testing Hess's Law

2. Predict the molar enthalpy of combustion of pentane using Hess's law and the given equations. (Assume that liquid water is formed.)
3. Calculate the molar enthalpy of combustion of pentane from the experimental evidence given in the exercise.
4. Compare your predictions with your experimental calculations and evaluate your results.

Check your answers by turning to the Appendix, Section 2: Activity 2.

Hess's Law

Reaction ①

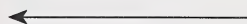
+

Reaction ②

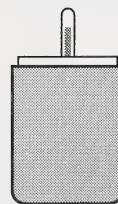
+

Reaction ③

can verify



can verify

**Calorimetry
Techniques**

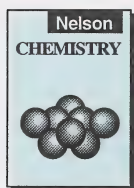
DID YOU KNOW?

Camera flashes used to work with disposable flashbulbs. The light produced by the flashbulb was the result of the energy change that occurred during the combustion of the magnesium filament in the bulb.

How could you determine the enthalpy change for the combustion of magnesium? Since the reaction is so rapid and much of the energy is released as light, could you use a simple polystyrene calorimeter to measure the enthalpy change? To answer this question, perform the following investigation.

Important Note – Disposal Information

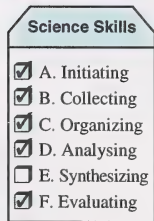
Any chemicals used in investigations in this module should not be poured down the sink unless indicated otherwise. Keep waste materials in closed, labelled containers. Contact your nearest high school or fire department for disposal information.

Investigation 11.1: Applying Hess's Law

Carefully follow the directions given for this investigation on pages 325-326 of your textbook. Pay special attention to the required components, safety aspects, and applied science skills.

Guidelines

- You should review the calorimetry techniques you used in performing Investigation 10.3: Molar Enthalpy of Reaction (on page 305 of your textbook) before you perform this lab.
 - Take careful note of the prediction and experimental design.
 - Figure 11.12 on page 326 of your textbook will provide you with important information for this investigation.
 - The precautions given on page 326 of *Nelson Chemistry* are particularly important.
5. Considering the experimental design and the materials given, list the steps to be followed in the procedure.



Check your answer by turning to the Appendix, Section 2: Activity 2.

PATHWAYS

If you have access to supervised laboratory facilities, do Part A.
If you do not have access to laboratory facilities, do Part B.

Part A

6. Prepare an evidence table, carry out your procedure, and record your observations.

Check your answers by turning to the Appendix, Section 2: Activity 2.

Complete your analysis by reading the instructions and doing the questions after Part B.

End of Part A

Part B

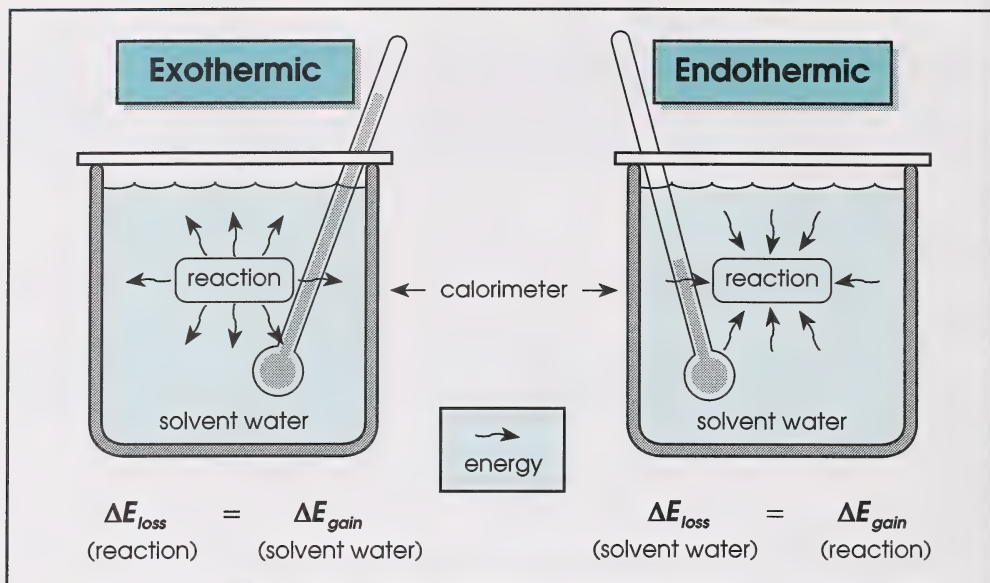
Because of possible problems in safety, you will not actually perform this investigation. Complete the investigation as instructed in the following question.

7. Prepare an appropriate evidence table and record the data from the evidence table given in the Appendix, Section 2, Activity 2, question 6.

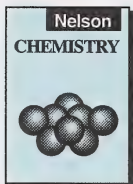
End of Part B

In Module 1, you performed Investigation 10.3 (as referred to earlier in the guidelines of this investigation) where a chemical reaction was performed in solution in a calorimeter. Investigation 11.1 is similar in that respect. It is worthwhile for you to review a few important points so that you have an easier time doing the analysis.

- In each case, a reaction is going on in solution, creating an energy change. The solvent water surrounding the reacting substances is then affected by the energy change. You measure that change by carefully monitoring the temperature change of the solution.
- You assume that the solution has the same specific heat capacity as water.
- You assume that no heat is lost to the surroundings other than the solvent water.
- When you do your calorimetry calculations, the reaction process is represented on one side of the mathematical equation and the solvent water is represented on the other side. Don't mix up your variables between the two sides.



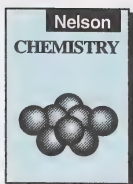
8. a. Using the mass of magnesium oxide and the temperature change for its reaction with hydrochloric acid, calculate the molar enthalpy of reaction for magnesium oxide.
- b. Using the mass of magnesium and the temperature change for its reaction with hydrochloric acid, calculate the molar enthalpy of reaction for magnesium.
- c. Use the three equations on page 325 of your textbook and the ΔH_f values that you calculated for the preceding two equations to calculate the molar enthalpy of combustion for magnesium. Manipulate the three information equations whatever way is necessary so they will add up to give the combustion reaction equation for magnesium.
9. Calculate your percent error using the information given under the heading Prediction on page 326 of your textbook and evaluate your investigation.



Check your answers by turning to the Appendix, Section 2: Activity 2.

Many processes in industry make use of the concepts you have developed in the preceding investigation. The next question introduces you to one of these processes.

10. Do textbook question 23 on page 342 of *Nelson Chemistry*.

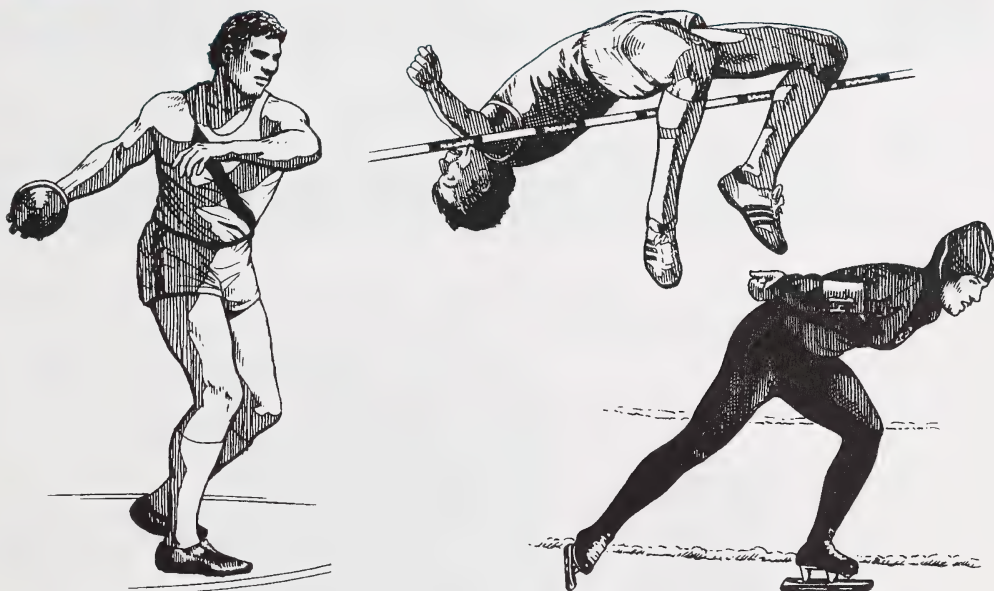


Check your answer by turning to the Appendix, Section 2: Activity 2.

You have seen that Hess's law can be used in a laboratory to determine the enthalpy change of a reaction which cannot be carried out directly in a simple calorimeter. Can you recall one other method you can use to determine enthalpy changes?

ACTIVITY

3

Predicting ΔH°_r with ΔH°_f 

1. From which point do you measure the distance, height, or time for each of the athletes portrayed in the graphic?

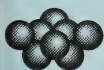
Check your answer by turning to the Appendix, Section 2: Activity 3.

Just like there is a **reference point** for measuring and comparing distances, heights, or times in athletic events, chemists have an arbitrary reference point to compare enthalpy changes for all chemical changes. Can you think of what this reference point is? To find the answer, read the bottom third of page 326 and the top half of page 327 in your textbook.

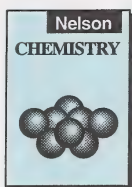
2. Describe what is meant by the *reference energy state*.

reference point
— a chosen, known fixed mark or standard against which an unknown can be measured

Nelson
CHEMISTRY



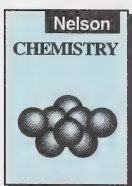
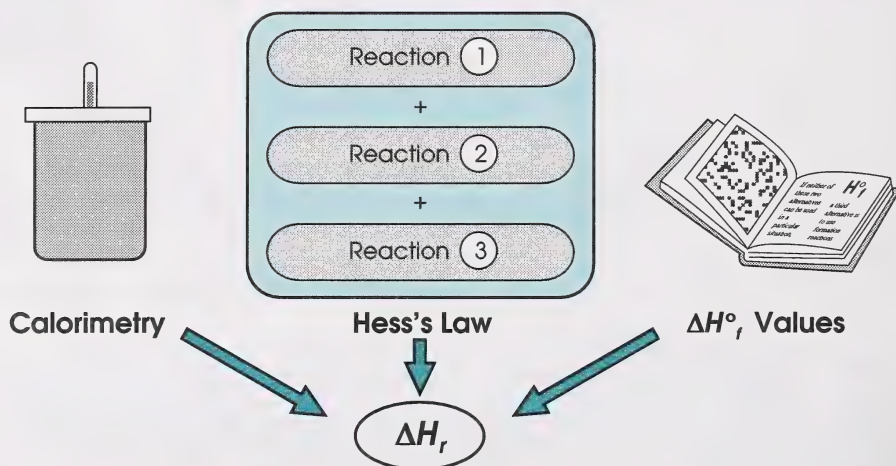
3. You have already dealt briefly with formation reactions in a previous section. How can a formation reaction be described? How can its enthalpy change be described?
4. Define thermal stability. What generalization can be made relative to thermal stability?
5. Using the Standard Molar Enthalpies of Formation chart on page 551 of your textbook, or your Chemistry Data Booklet, list the following compounds in decreasing order of stability (in terms of energy):



- carbon disulphide ($\text{CS}_{2(l)}$)
- ethyne ($\text{C}_2\text{H}_{2(g)}$)
- magnesium chloride ($\text{MgCl}_{2(s)}$)
- hydrogen bromide ($\text{HBr}_{(g)}$)

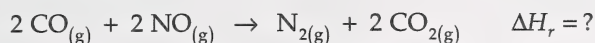
Check your answers by turning to the Appendix, Section 2: Activity 3.

You have already seen how the enthalpy change of a reaction can be found either by calorimetry methods or by using Hess's law.



Read the bottom half of page 327 and all of page 328 in your textbook; you will see an example of how formation equations, along with their ΔH°_f values, can be used to determine the enthalpy change of a reaction. You will also see how an enthalpy change for a reaction can be found using only the H°_f values themselves.

6. Outline the steps you would use to determine the enthalpy change for a reaction using formation equations. Find the enthalpy change for the following example equation to guide your explanation:



7. Write the mathematical equation that illustrates how the enthalpy change of a reaction can be found using enthalpies of formation. Label the parts of the equation.

Check your answers by turning to the Appendix, Section 2: Activity 3.

As you probably already realize, the method of using molar enthalpy of formation values for determining the enthalpy change of a reaction is just an extension of Hess's law.



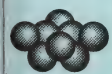
Two important points to keep in mind when using this *products minus reactants* method are as follows:



It is the product enthalpy of formation values minus reactants – not the other way around.



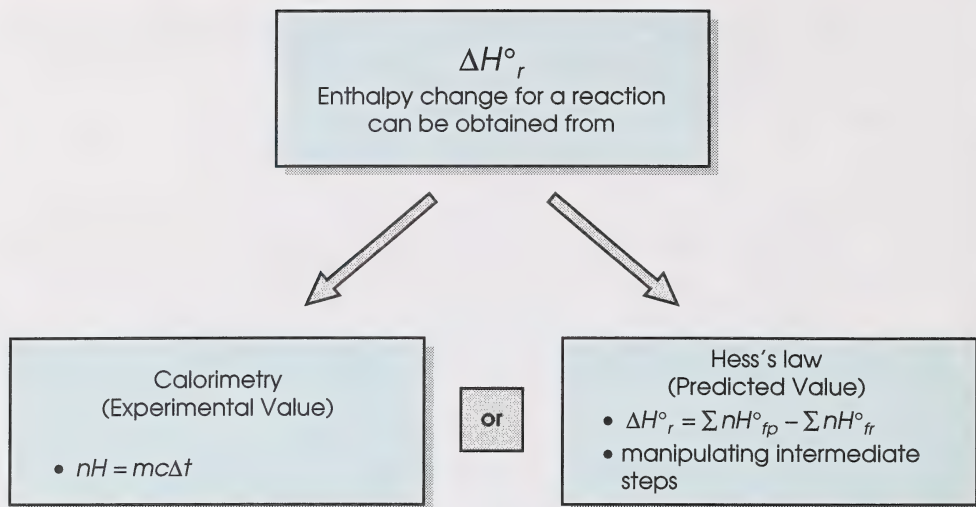
When substituting molar enthalpy of formation values into the equation $\Delta H_r^\circ = \sum nH_{fp}^\circ - \sum nH_{fr}^\circ$, do NOT change any signs on the values. The equation is set up to automatically account for whether the enthalpy values are for products or reactants – you don't have to reverse any signs.



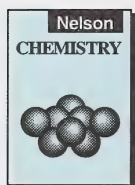
An example of the products minus reactants method is given on page 329 of your textbook. Study the example; then do the following questions.

8. What is the advantage of using enthalpies of formation for calculating enthalpy changes of chemical reactions?
9. Answer textbook questions 11-14 on pages 329-330 of *Nelson Chemistry*.

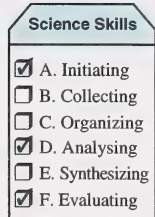
Check your answers by turning to the Appendix, Section 2: Activity 3.



Lab Exercise 11C: Testing ΔH°_r from Formation Data

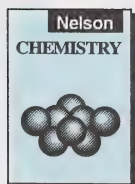


To test the prediction of heat of combustion from molar enthalpies of formation you will do Lab Exercise 11C on page 330 of your textbook. Read the information given; then answer the following questions to complete the exercise. Pay special attention to the applied science skills.

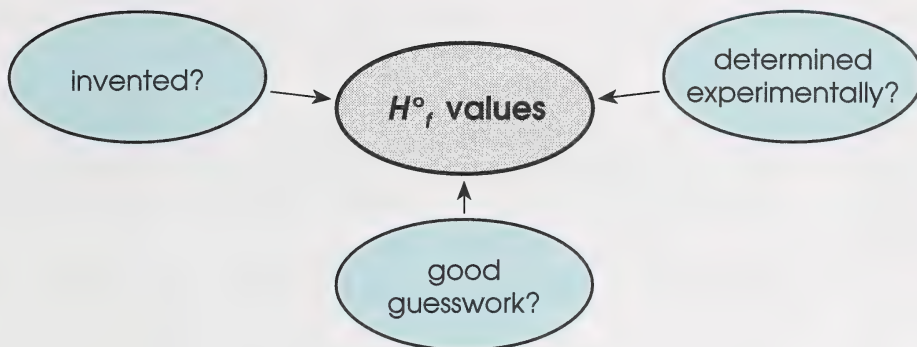


10. Using the equation $\Delta H^\circ_r = \sum nH^\circ_{fp} - \sum nH^\circ_{fr}$, predict the molar enthalpy of combustion for methanol, $\text{CH}_3\text{OH}_{(l)}$. First, write the combustion equation. Then show your mathematical work underneath.
11. Use the evidence given on page 330 of your textbook to calculate the experimental molar enthalpy of combustion for methanol.
12. Evaluate the method of using molar enthalpies of formation to find the enthalpy change of a reaction (products minus reactants) by comparing the predicted and experimental values in this lab exercise.

Check your answers by turning to the Appendix, Section 2: Activity 3.



You have been using the molar enthalpy values from the Standard Molar Enthalpies of Formation table on page 551 of your textbook quite a bit. Where do these values come from?



All the standard molar enthalpy values were determined through experimental measurements. However, not all of the substances could be formed directly from their elements to determine their H°_f values. How else could they have been determined? One way is working *backwards*. For example, the standard molar enthalpy of sugar or sucrose, $C_{12}H_{22}O_{11(s)}$, can be determined by completely burning a sample of sugar in a bomb calorimeter; then using the H°_c value to determine H°_f values.

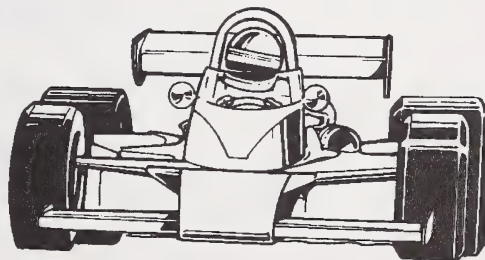
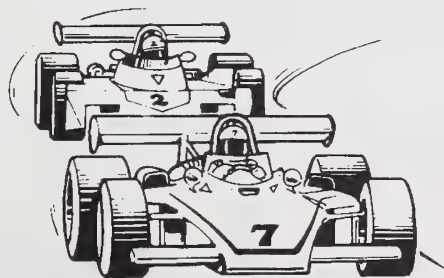
Lab Exercise 11D: Determining Standard Molar Enthalpies of Formation

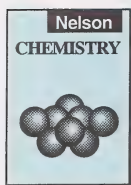
To see how this process is carried out with another substance, hexane, do Lab Exercise 11D on pages 330-331 of your textbook. Pay special attention to the applied science skill.

13. Complete the analysis of the investigation report given in Lab Exercise 11D. Organize your work carefully, showing all your equations and calculations.

Check your answers by turning to the Appendix, Section 2: Activity 3.

Do you know which fuel is used in some racing cars? Many organic compounds, like cyclohexane, make good fuels for high-performance racing cars.





Science Skills

- ☐ A. Initiating
☐ B. Collecting
☐ C. Organizing
☒ D. Analysing
☐ E. Synthesizing
☐ F. Evaluating

14. To find out what the molar enthalpy of cyclohexane is, complete the analysis of Lab Exercise 11F: Molar Enthalpy of Formation on page 339 of your textbook. Pay special attention to the applied science skill.

Check your answer by turning to the Appendix, Section 2: Activity 3.

Hess's law can be extended to using molar enthalpies of formation to calculate enthalpy changes for chemical reactions. It is also an important tool for determining the molar heats of formation for substances when calorimetry cannot be used, either because the temperature changes involved are very small or the process is very slow.

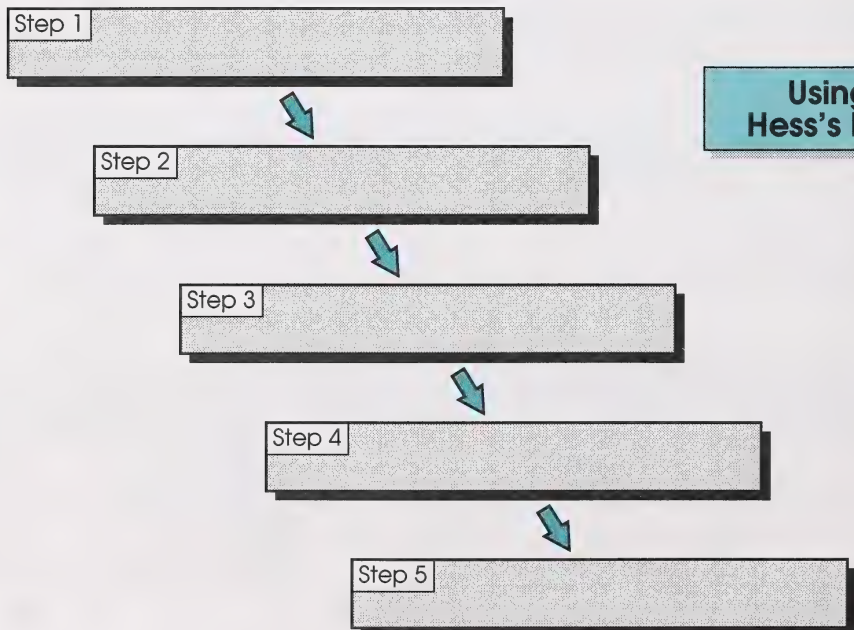
Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

Review the main concepts covered in this section by doing the following questions.

1. Draw and label boxes similar to the following. Fill in the boxes by describing the steps involved in finding the enthalpy change of a chemical reaction by using Hess's law of heat summation.





When using Hess's law

- If an information equation is reversed, the sign on the enthalpy value is changed.
- If an information equation is multiplied by a factor, so is its enthalpy value.
- Information equations are chosen not only to give required substances, but for cancelling unwanted substances as well.

2. Use Figure 2.3 to answer this question.

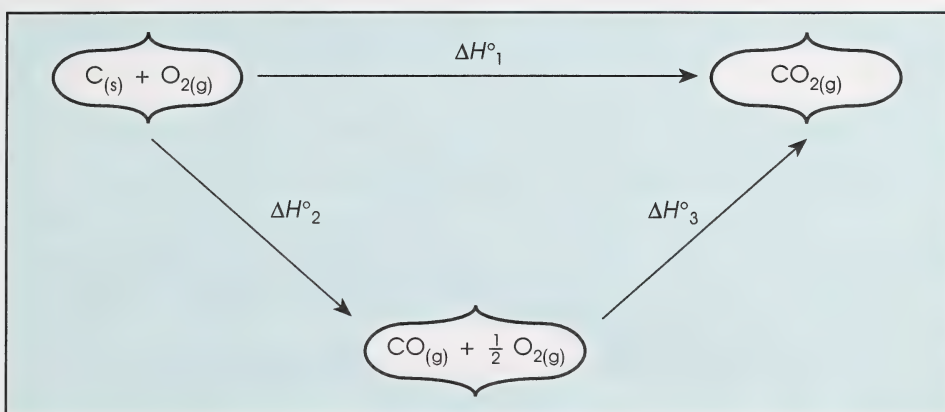


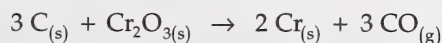
FIGURE 2.3: Formation of Carbon Dioxide

a. Complete the following relationship.

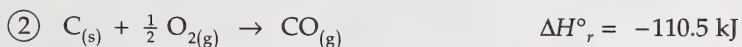
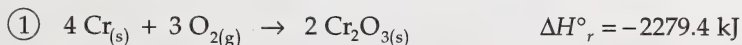
$$\Delta H^\circ_1 = \text{_____} + \text{_____}$$

b. If the value for ΔH°_1 is -393.5 kJ and the value for ΔH°_3 is -283.0 kJ , what is the value for ΔH°_2 ?

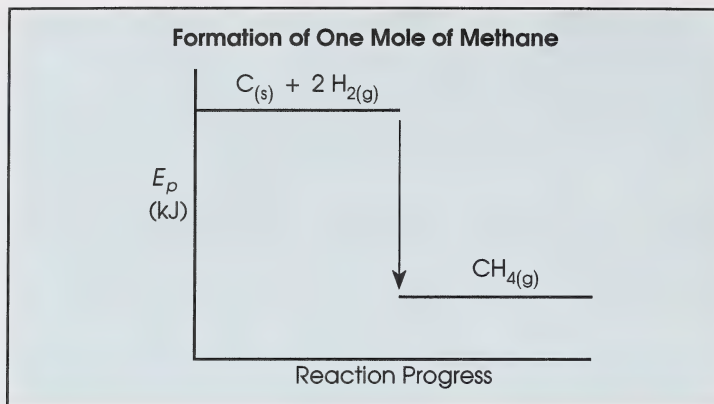
3. You are given the following reaction equation:



Calculate the energy change for the given reaction from the following information equations:



4. Use the following potential energy diagram to answer this question.



Would you predict that methane, $\text{CH}_{4(g)}$, would be more stable or less stable than the reactants from which it was formed? Explain.



When predicting the enthalpy change of a reaction using H°_f (heat of formation) values

- Make sure that you set up the math equation as **products minus reactants**, that is,

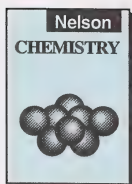
$$\Delta H^\circ_r = \sum nH^\circ_{f \text{ [p]}} - \sum nH^\circ_{f \text{ [r]}}$$

- Don't forget to include the coefficients from the desired equation as multiples when working with the H°_f values.

5. Find the enthalpy change for the combustion of glucose reaction (as shown) using heat of formation values.



Check your answers by turning to the Appendix, Section 2: Extra Help.



If you would like further practice in working with the concepts presented in this section, answer any of questions 4, 8, 9, 20-25 on pages 340-342 of your textbook. The answers to these questions can be found on pages 513-514 of *Nelson Chemistry*.

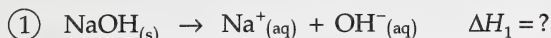
Enrichment

Do any **one** of the following:

Science Skills

- ☒ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☒ D. Analysing
- ☒ E. Synthesizing
- ☒ F. Evaluating

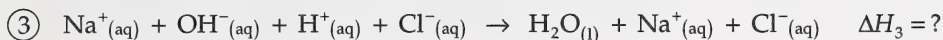
1. Hess's law can be used to show the relationship between the following three reactions:



(Solid sodium hydroxide is dissolved in water.)



(Solid sodium hydroxide is mixed with a solution of hydrochloric acid.)



(A solution of sodium hydroxide is mixed with a solution of hydrochloric acid.)

The relationship between the reactions can be confirmed experimentally using calorimetry techniques.

- a. Illustrate the relationship between Reactions $\textcircled{1}$, $\textcircled{2}$, and $\textcircled{3}$ using Hess's law. (**Hint:** One reaction represents the combination of the others.)
- b. Design a calorimetry investigation that could confirm the relationship between the three reactions.
- c. Write a procedure for the investigation, using the following materials as guidelines:

Reaction $\textcircled{1}$	Reaction $\textcircled{2}$	Reaction $\textcircled{3}$
• 2.0 g $\text{NaOH}_{(s)}$/trial • 100 mL $\text{H}_2\text{O}_{(l)}$/trial	• 2.0 g $\text{NaOH}_{(s)}$/trial • 100 mL of 0.50 mol/L HCl/trial	• 50.0 mL of 1.00 mol/L $\text{NaOH}_{(aq)}$/trial • 50.0 mL of 1.00 mol/L $\text{HCl}_{(aq)}$/trial

Note: If you have access to supervised laboratory facilities, you can actually perform this investigation. Pay careful attention to all safety and disposal procedures.

2. Research and collect some information regarding the Born-Haber cycle. This cycle is a five-step process illustrating the formation of ionic compounds from their elements. Use Hess's law to show how these steps combine to create the overall process.

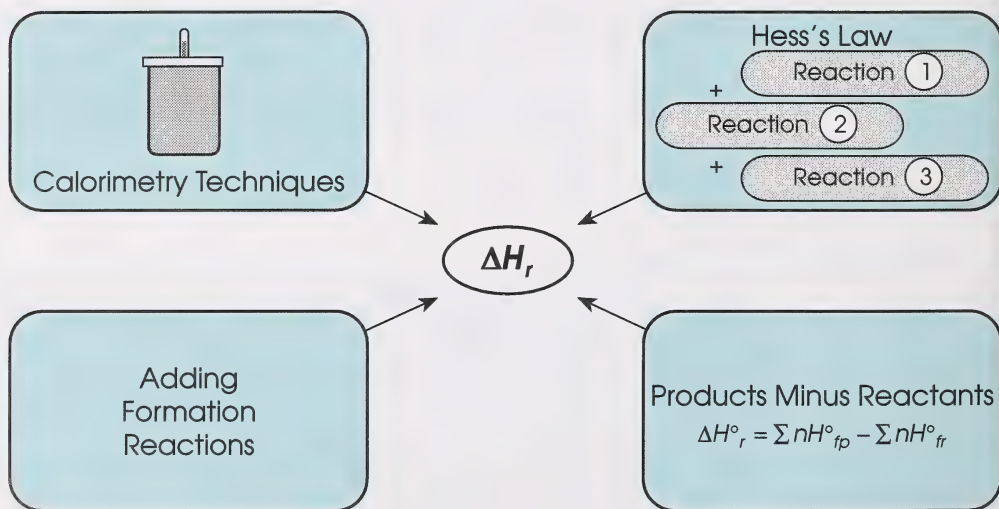
3. Visit a fertilizer plant and talk to an expert to discover how chemical engineers and experimental chemists have developed a multi-step process, the Haber-Bosch process, to produce ammonia fertilizers.

Check your answers by turning to the Appendix, Section 2: Enrichment.

Conclusion

Whether it is chemical changes occurring in living systems or in industrial processes, enthalpy changes can be determined using Hess's law. The law has wide application. You have seen how the predicted results from several Hess's law applications have been tested and verified using experimental results from calorimetry.

You were introduced to several reliable methods for determining the enthalpy change of a reaction.



In the next section you will examine some energy alternatives to the fuels used by society and assess some of the risks involved with the alternatives.

Section 2 Assignment: Energy Is Predictable

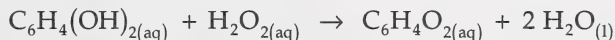
Review the Evaluation information found in the introductory pages of this module.

It is important to number and clearly identify each page with the following information at the top:

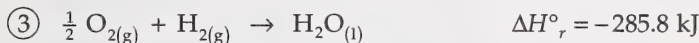
Chemistry 30 – Module 2 Section 2 Assignment Page # Name and ID#

Be sure to write legibly. Leave a wide left margin and number all of your pages.

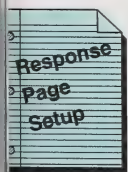
- The bombardier beetle uses the following explosive reaction as a defence mechanism. The product acts as a repellent.



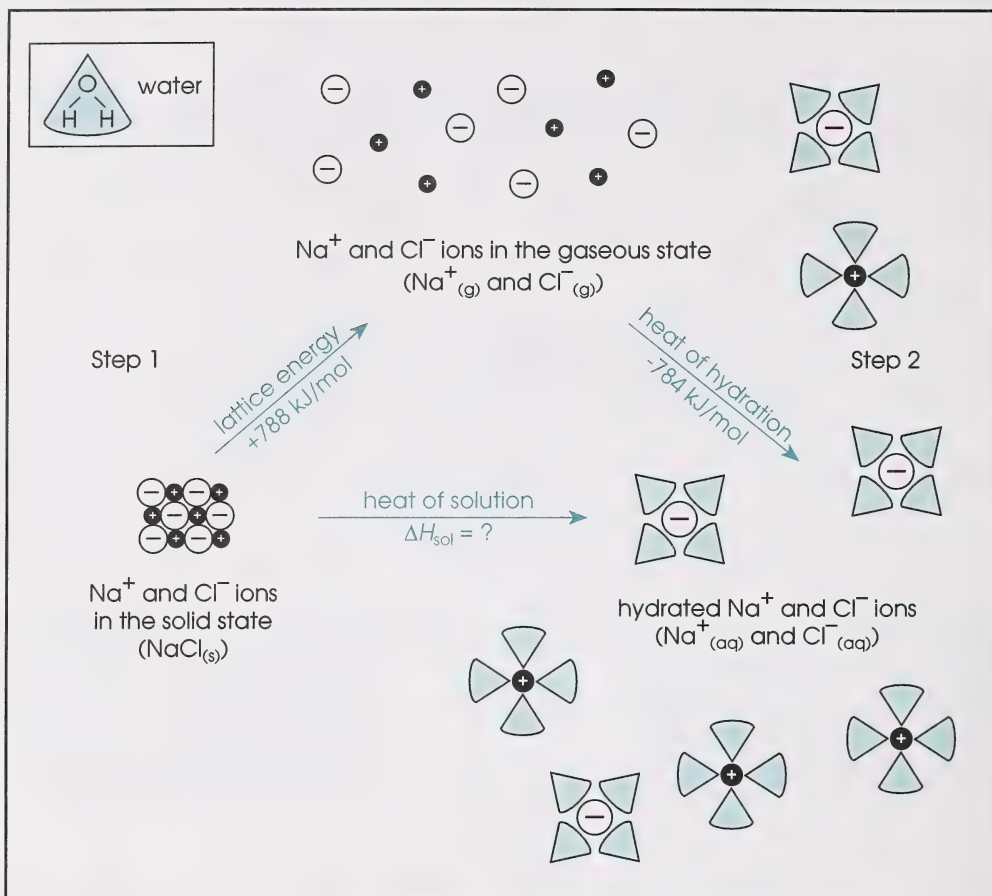
Calculate the enthalpy change for the reaction from the following information equations. Show your complete work. **(4 marks)**



- Sulphur trioxide gas ($\text{SO}_{3(\text{g})}$) and water can react under appropriate conditions to form sulphuric acid in the atmosphere. The reaction is responsible for much of the acid rain that is affecting the environment.
 - What is the enthalpy change when one mole of the acid forms from $\text{SO}_{3(\text{g})}$? Show your complete calculations. Assume that the water is liquid and the sulphuric acid is liquid. **(4 marks)**
 - Draw a labelled potential energy diagram to represent the change. You do not have to use graph paper. Your graph axes should be between 5 cm and 7 cm long. **(2 marks)**

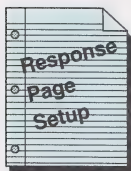


3. Use the given diagram to answer this question.



Calculate the heat of solution for one mole of NaCl_(s). Show your work completely. (2 marks)

4. Aluminum metal reacts with solid copper(II) oxide to form copper metal and solid aluminum oxide.

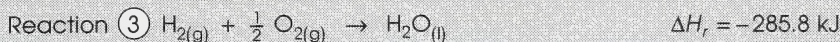


- Write the equation (balanced with whole numbers) representing this reaction and show any necessary calculations to find the enthalpy change for two moles of aluminum reacting. (4 marks)
- Draw a labelled potential energy diagram for this reaction. You do not have to use graph paper. Your graph axes should be between 5 cm and 7 cm long. (2 marks)

Science Skills

- ☐ A. Initiating
☐ B. Collecting
☐ C. Organizing
☒ D. Analysing
☐ E. Synthesizing
☐ F. Evaluating

5. A student is required to determine the molar enthalpy (heat) of combustion for calcium in the reaction $\text{Ca}_{(s)} + \frac{1}{2} \text{O}_{2(g)} \rightarrow \text{CaO}_{(s)}$, using the following reactions and the data collected.



Reaction	Mass	Volume of 1.0 mol/L $\text{HCl}_{(aq)}$	Initial Temperature	Final Temperature
①	0.50 g $\text{Ca}_{(s)}$	$1.00 \times 10^2 \text{ mL}$	22.3°C	35.9°C
②	1.50 g $\text{CaO}_{(s)}$	$1.00 \times 10^2 \text{ mL}$	22.0°C	29.1°C

Assume the specific heat and density of $\text{HCl}_{(aq)}$ are the same values as for water.

Show your complete work in each part of this question.

- Determine the molar enthalpy (H_r) value for calcium solid in Reaction ①. (4 marks)
- Determine the molar enthalpy (H_r) value for calcium oxide solid in Reaction ②. (4 marks)
- Using Reactions ①, ②, and ③ determine the ΔH_r value for the combustion of calcium metal. (4 marks)

Reproduce the science skills assessment box after your response to this question. Remember to indicate your evaluation of your skill level for each identified science skill. Leave a space for the teacher assessment.

Self: A.	☐	B.	☐	C.	☐	D.	☐	E.	☐	F.	☐
Teacher: A.	☐	B.	☐	C.	☐	D.	☐	E.	☐	F.	☐

SECTION

3

Energy Alternatives and Society



CANADIAN NUCLEAR ASSOCIATION

The CANDU nuclear power plant pictured in the photograph uses uranium as a fuel. Other power plants in the country may use coal as fuel for generating their power. Still others may use oil as their power source. For the same mass, which fuel do you think releases more energy? One kilogram of uranium fuel releases the same amount of energy as about fifty-five tonnes (55 000 kg) of coal or forty-one tonnes (41 000 kg) of oil! However, enthalpy change is not the only criteria used to decide which fuel should be used by industry and society. Experts assess the risks and benefits for specific applications to select the most appropriate fuel. Can you think of some of the risks and benefits of using uranium, coal, or oil as fuels?

In this section you will first explore the nature of nuclear changes which release extremely large amounts of heat energy. You will then look at some alternative energy sources and evaluate the benefits and risks involved in their use. Lastly, you will solve some energy problems which require a combination of several steps.

ACTIVITY

1 Nuclear Energy

nuclear change
– a change in the nucleus of an atom which results in the formation of a different type of atom or atoms with a large release of energy

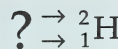
What is the most common type of **nuclear change** that is familiar to you? Likely, your answer is the nuclear reactions taking place in the sun! These reactions are responsible for heating the Earth, even though the sun is 150 000 000 km (150 million km) away! Nuclear changes are not only responsible for the solar energy used by green plants, medical diagnostic techniques, and a portion of the electrical energy generated world-wide, but a host of other factors. This activity will explore some of these factors.

To introduce you to the nature of nuclear changes, read section 11.3 Nuclear Reactions on page 331 of your textbook. Don't forget the margin information.

1. How does an enthalpy change come about in a nuclear reaction (what is it a result of)?
2. What is the name given to the main type of nuclear reaction that occurs in the sun? What is involved in this type of reaction?
3. The following reaction is similar to the nuclear change that occurs in the sun.



What do the numbers on the symbols of the elements represent?



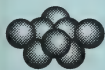
4. Why are fossil fuels considered a stored form of solar energy?

Check your answers by turning to the Appendix, Section 3: Activity 1.



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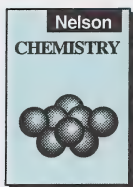


nuclear fusion – a nuclear change where smaller nuclei are fused together to make larger nuclei

The example of a **nuclear fusion** reaction mentioned in question 3,



is becoming of increasing interest to scientists and engineers as a potentially clean and renewable source of energy. However, an energy-efficient, controllable design of a nuclear fusion reactor is still a number of years away.



nuclear fission – a nuclear change involving the splitting of an atomic nucleus into smaller nuclei

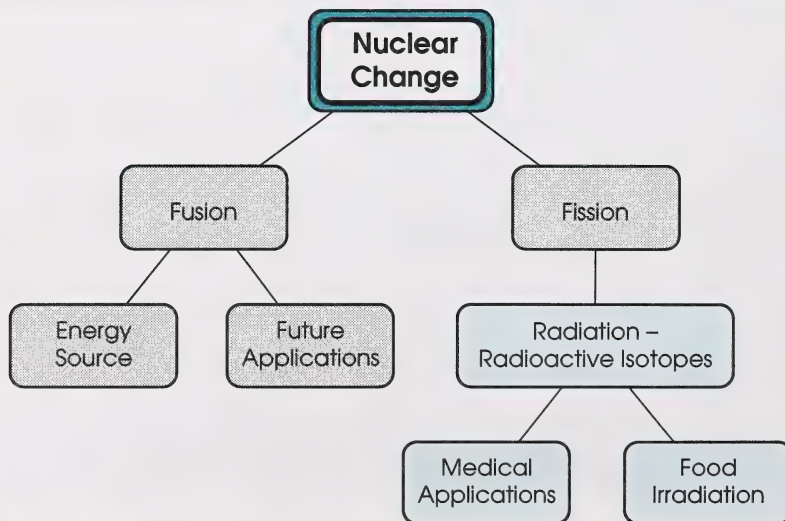
The nuclear reactors presently in use operate on the principle of a **nuclear fission** reaction. To see an example of the type of reaction involved, read the small section at the top of page 332 in your textbook.

5. a. Write the nuclear equation for the reaction of uranium-235 (which means ${}^{235}_{92}\text{U}$) in a nuclear fission reaction. Write the energy term using ΔH_f notation.
- b. The mass number of radioactive **isotopes** tells you the molar mass of the particular isotope. For instance, the molar mass of uranium-235 is 235 g/mol. Using this information, and the nuclear reaction from 5.a., calculate the enthalpy change of the uranium fission reaction if 25.0 g of uranium-235 is reacted.
6. If you were given a variety of different equations, how would you recognize the equation that represents a nuclear change?

Check your answers by turning to the Appendix, Section 3: Activity 1.

isotopes – atoms of the same element with different numbers of neutrons

Nuclear changes are not simply restricted to the fusion reactions occurring in the sun or the fission reactions in nuclear reactors.



radiation – energy that travels through space in the form of waves or particles

Radiation is a form of nuclear change, and it is all around you. Radiation is a fact of life and can't be avoided. The chart in Figure 2.4 gives the measured dosage of radiation you can expect to get in the home, on the street, and from medical procedures. For most people, the combined dosages will fall well below the established safe level of 500 millirems per year (5 msv).¹

7. Complete the given chart. Compare your annual radiation dose with the average and safe limit given.

Compare Your Annual Radiation Dose (Calculated as Dose to Bone Marrow)		
	Source of Exposure	Your Annual Dose (Millirems)
Where you live	Natural cosmic radiation at sea level (Add 3 for every 150 m above sea level.)	28 _____
	Ground	26
	Radon gas	80
	House construction (based on 18 h/day in house) (masonry = 7; wood = 0)	_____ _____
What you eat, drink, and breathe	Naturally occurring radio-nuclides in food and water	24
	Fallout from previous nuclear weapons tests	4
How you live	10 000 km jet flight (cosmic radiation during flight = 4; number of flights per year × 4)	_____ _____
	Chest X-ray (number per year × 10)	_____ _____
	Upper gastrointestinal X-ray (number per year × 535)	_____ _____
	Dental X-ray (number per year × 10)	_____ _____

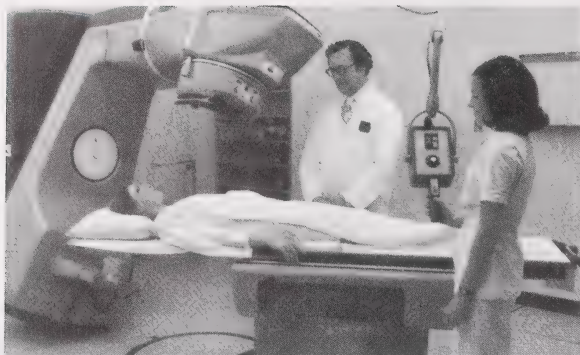
Living near CANDU nuclear station	At reactor site boundary = 2	
	1.6 km from boundary = 0.7	
	8 km from boundary = 0.1	_____ _____
TOTAL		_____ _____
Compare your average with the North American average of 260 millirems or 2.6 msv.		

FIGURE 2.4: Annual Radiation Dose

2

¹ Reprinted with permission from the Canadian Nuclear Association, *Nuclear Facts*, Number 13, 3-1989.

² Ibid.



CANADIAN NUCLEAR ASSOCIATION

Radioactive isotopes and radiation of various forms have been used for a number of years for medical procedures and food preparation. What are the health benefits of radiation? Radiation is widely used today in medical treatment, diagnosis, and research. Cancer therapy machines, as shown in the photograph, use the radioisotope cobalt-60 in the treatment of more than one million people around the world each year.

How does Canada's nuclear power program relate to medicine? Atomic Energy of Canada Limited produces about 85% of the world's cobalt-60 from its Canadian nuclear reactors. Cobalt-60 has been used in the treatment of cancer for over thirty years.

Cobalt-60 is also used in the food irradiation process. The irradiation of foods such as potatoes has been allowed in Canada since 1960. Is irradiated food radioactive? A dental X-ray does not make you radioactive, and neither does irradiated food.

Obviously, as a consumer, you have to make your own decision as to whether or not you agree with the treatment of cancer using radiation, or the irradiation of foods. The last activity in this section will hopefully help you to assess the value of such technologies so that you can make an informed and rational decision.

The following two questions may require extra research.

8. What is the purpose of irradiating foods with cobalt-60?
9. What are some other uses for cobalt-60?



CANADIAN NUCLEAR ASSOCIATION

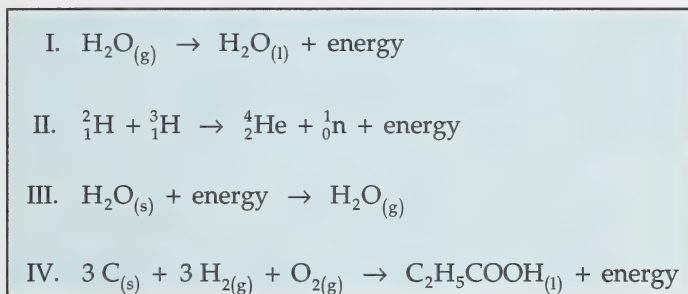
Check your answers by turning to the Appendix, Section 3: Activity 1.

Through your studies in Modules 1 and 2 so far, you have looked at the energy changes in phase changes, chemical changes, and nuclear changes. The following questions compare these various types of changes.

10. Fill in a table similar to the following.

Type of Change	Type of Energy	Types of Bonds Involved
Phase		
Chemical		
Nuclear		

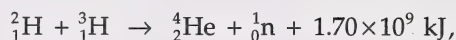
11. List the three types of changes studied and indicate beside each the relative magnitude of the energy change expected for each. (Note: The values required here are general in nature and will have exceptions.)
12. Use the following equations to answer this question.



Match each the following statements to its applicable equation.

- a. This is a sublimation reaction.
 - b. Energy change involved is of the magnitude 10 kJ/mol-100 kJ/mol.
 - c. This involves making and breaking proton-neutron bonds.
 - d. Energy change is a result of a chemical change.
13. Which of the following reactions will release the most energy per mole?
- a. $\text{H}_{2(g)} \rightarrow \text{H}_{2(l)}$
 - b. $\text{H}^+_{(g)} + \text{e}^- \rightarrow \text{H}_{(g)}$
 - c. $\text{H}_{(g)} + \text{H}_{(g)} \rightarrow \text{H}_{2(g)}$
 - d. ${}^1_1\text{H} + {}^{15}_7\text{N} \rightarrow {}^{12}_6\text{C} + {}^4_2\text{He}$

14. If an enthalpy change of 6.50×10^{10} kJ was recorded from a reaction represented by the following equation,



calculate the mass of ${}^3_1\text{H}$ that reacted. (Hint: The symbol ${}^3_1\text{H}$ represents one mole of ${}^3_1\text{H}$. If there had been two moles, it would have been written as $2 {}^3_1\text{H}$.)

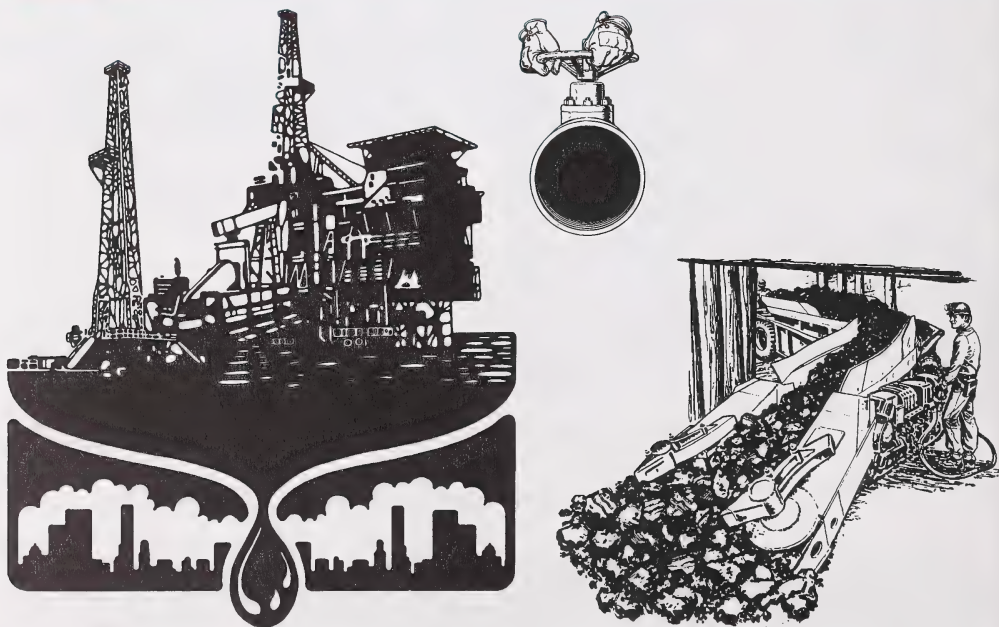
Check your answers by turning to the Appendix, Section 3: Activity 1.

You have looked at the nature of nuclear reactions. In the last few decades the number of nuclear power plants have increased to meet the energy needs of the industrialized society in which you live. However, the much-publicized Chernobyl nuclear disaster, along with some others, has slowed the rate at which these plants are being constructed. The quest for alternatives to fossil fuels continues.

ACTIVITY

2

Energy Alternatives



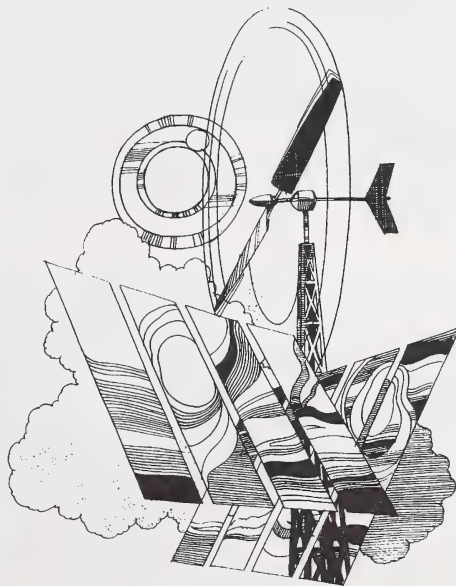
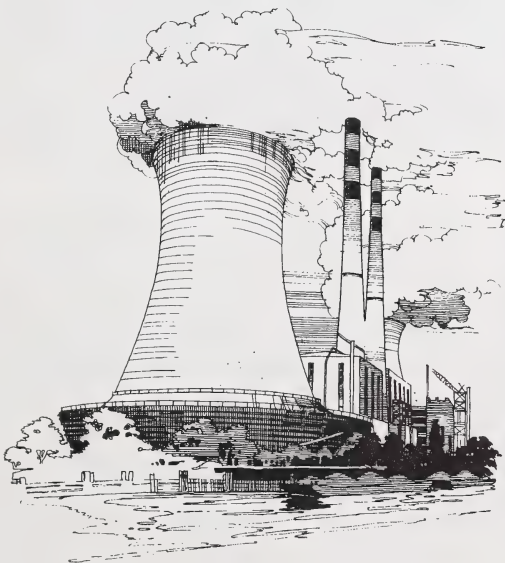
What do the fuels depicted by the preceding graphics have in common? Whether you refer to oil, coal, or natural gas, they are all fossil fuels. The large amounts of chemical potential energy stored in the bonds of these fuels make them valuable as an energy source. Fossil fuels still remain the most common type of fuels used by society today.

The section 11.4 Energy and Society on page 332 of your textbook gives a brief overview of fossil fuels and society's demand for them. Read this section; then answer the following questions.

1. List the three major demands for energy from fossil fuels.
2. What are three problems associated with the burning of fossil fuels?
3. Global warming has been attributed in large part to the extensive use of fossil fuels in industrialized society. Read the section titled Global Warming on page 294 of your textbook and then briefly define global warming.

Check your answers by turning to the Appendix, Section 3: Activity 2.

Besides affecting the environment adversely, natural sources of oil and other related fuels are getting depleted. Many alternative fuels are now being seriously considered and researched.



Solar, wind, hydro, and nuclear sources of energy are just some of the alternative energy sources being explored.

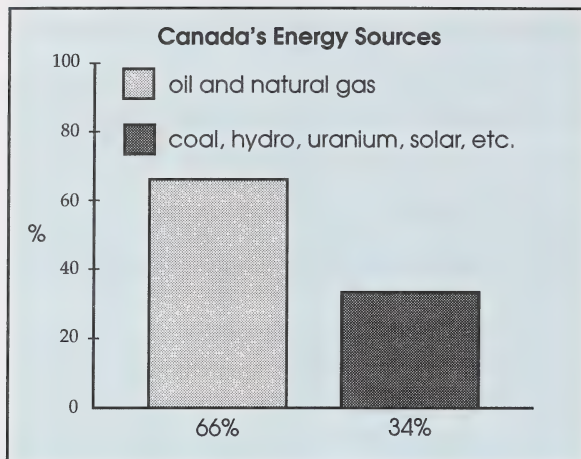


FIGURE 2.5: Canada's Energy Sources

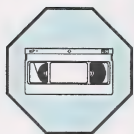
Canadians already use some of these different energy sources. Figure 2.5 shows, approximately, the percent distribution of Canada's energy needs being met from some alternative sources.

Because of the growing concern about fossil fuels regarding their affect on the environment and their non-renewable nature, scientists and technology experts have also been looking at liquid fuels such as ethanol as an energy source. The following video gives you a brief look at ethanol as an alternative energy source.

VIDEO

If you have access to the video entitled *Chemical Energy*, do Part A.
If you do not have access to this video, do Part B.

Part A



To learn about liquid fuels such as methanol and ethanol, watch the last part of the video *Chemical Energy* (starting at 18 minutes) starting with the section titled Liquid Fuels from Biomass. Review the questions that come after Part B before you start watching the video. Then, answer the questions after Part B to check your understanding.

End of Part A

Part B

Read the following material before answering the questions after Part B.

Alternative Energy Sources

Liquid fuels, such as oil and gasoline, are in the greatest demand by society today because of convenience and cost-efficiency. However, these fossil fuels are declining in supply. Renewable alternatives are desired.

biomass – plant materials

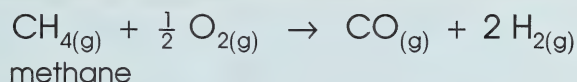
Much research is being done at present, exploring the concept of using **biomass** to produce liquid fuels. This would include using algae, waterweeds, grass, trees, and plant waste products. Liquid fuels such as methanol and ethanol are promising prospects as liquid fuels from these materials.

Methanol can be produced from wood – in which case it is called wood alcohol. A more economical method of producing methanol, however, is to start with methane (natural gas). The reaction equations for this process are given in the following diagram.

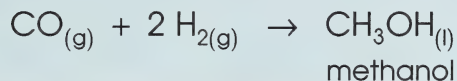


WESTFILE INC.

Step 1



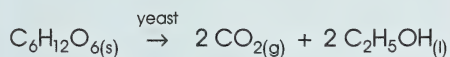
Step 2



The methanol can be burned itself, but is more often used as an additive to gasoline. Other promising research is in the area of using methanol in a fuel cell which provides electricity to run an electric vehicle.

Ethanol produced from biomass material is used extensively as a car fuel in Brazil. The ethanol is made from starch or sugar by fermentation (reaction) with yeast. The ethanol is distilled (boiled off) several times from a watery solution to dry the ethanol. One problem with the distillation process is its efficiency. The distillation process is too energy-consuming.

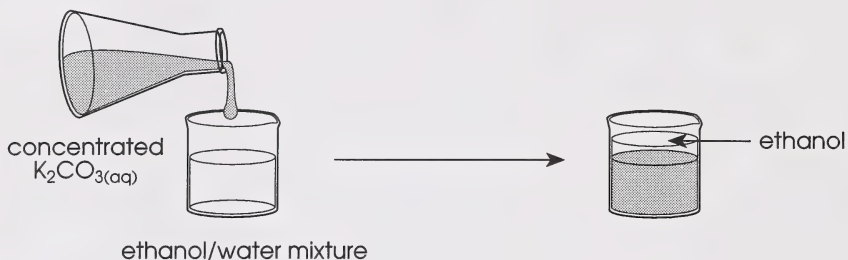
Efficiency



For every 100 kJ made in ethanol

growing/processing	– 15 kJ
distillation	– 70 kJ
production uses up =	85 kJ

The latest method of separating the ethanol from its watery solution is the treatment of the solution with concentrated potassium carbonate. When treated in this fashion, the ethanol separates and floats to the top in a low-energy process.



cellulose – a plant polysaccharide that makes up the walls of plant cells

lignin – a natural polymer that combines with cellulose to form the woody cell walls of plants and the cement between them

Ethanol can also be produced from **cellulose**, however, not directly by yeast. The **lignin** coating on the cellulose and the different bonding of the sugar molecules makes the cellulose tougher to break down. Acid is first used to remove the outer lignin coating, enzymes reduce the cellulose to sugar molecules, and then the sugar molecules can be fermented to produce ethanol.

As with any emerging material such as ethanol and the technology to use it, environmental and economic questions should be asked:

- Should standing forests be used to produce the ethanol?
- Will tree farming deplete the soil or will it improve damaged soil?
- Is the expense of the technology required to utilize the ethanol worth the effort?

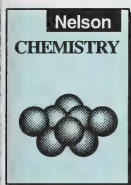
The problem at present is that pumping oil out of the ground is still the cheapest and easiest method of providing fuel energy.

End of Part B

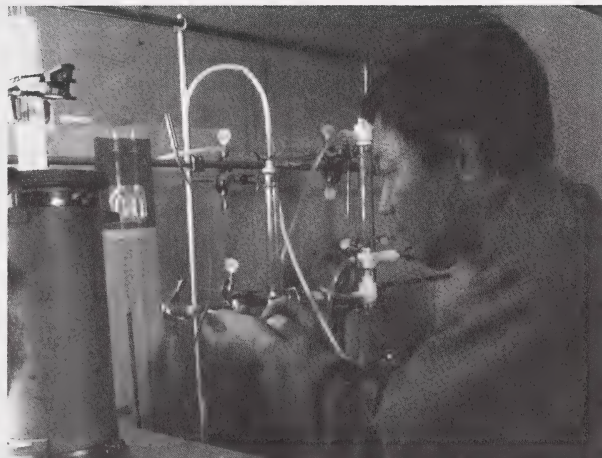
4. What is biomass?
5. The more economical method of producing methanol is from methane gas.
 - a. Write the two equations involved in the process. Use Hess's law to determine the enthalpy change for the net overall equation.
 - b. Draw a potential energy diagram to represent the methanol production.
6. What country uses ethanol extensively as a fuel?
7. How is ethanol produced?

8. a. How efficient is the distillation method of producing ethanol? Explain.
b. Briefly describe a relatively new method of recovering ethanol using potassium carbonate.
9. What two factors make cellulose harder to break down than starch to produce ethanol?
10. What are two environmental questions that should be asked when considering the production of ethanol?
11. Why is the use of ethanol not widely considered at present?

Check your answers by turning to the Appendix, Section 3: Activity 2.



To have a healthy environment requires a decreased amount of emissions from cars and industry. Some American cities are proposing laws which require at least 10% of the cars to be exhaust free. This can happen only if a fuel such as hydrogen or an energy source like electricity are used. The scientist shown in the photograph is developing a device for recovering hydrogen and sulphur from hydrogen sulphide gas. A significant amount of research has gone into the testing of hydrogen as a fuel for vehicles. Figure 11.21 on page 333 of your textbook shows a car that uses hydrogen as a fuel.

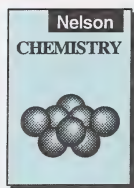


AOSTRA

12. What will be the environmental impact of emissions from this hydrogen-burning car?
13. How is the hydrogen stored in the car?

Check your answers by turning to the Appendix, Section 3: Activity 2.

Whatever alternative energy sources you focus on, they all come at a price. Society and you must make informed decisions about which sources of energy will sustain the Earth and its people into the future.

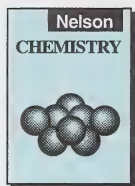


To make these kinds of decisions, a logical method of decision making must be used in order to achieve the best end result. Examine the decision-making model given in Appendix D on page 538 of your textbook to see one method of making decisions. Use this method to answer the following question.

14. Do you feel that ethanol is a good alternative source of fuel? Defend your decision based on scientific, technological, ecological, and economic perspectives. (There is no right or wrong answer to this question.)

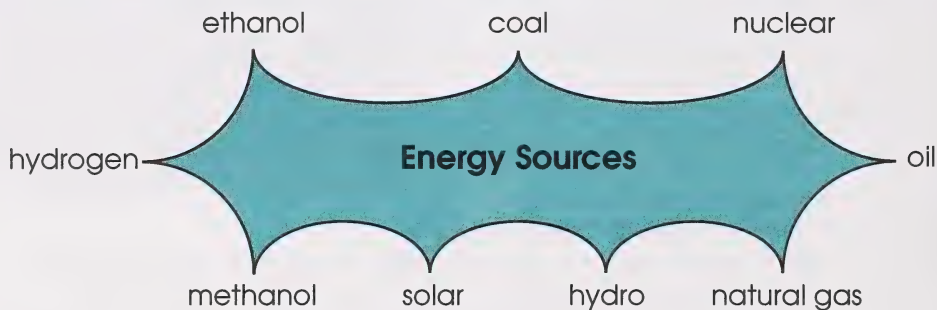
Check your answer by turning to the Appendix, Section 3: Activity 2.

To complete this activity, do the following textbook questions.



15. Answer textbook questions 19-24 on page 337 of *Nelson Chemistry*.

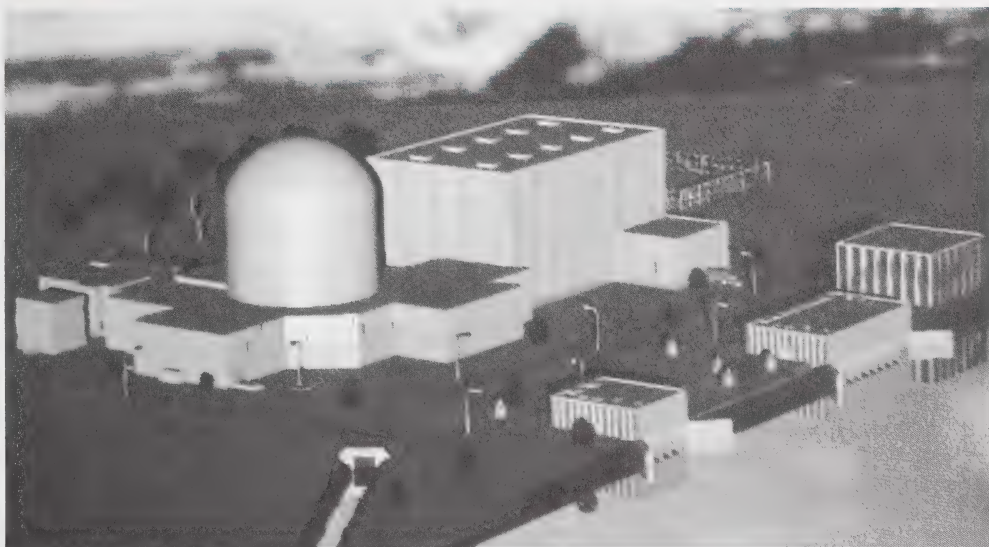
Check your answers by turning to the Appendix, Section 3: Activity 2.



In this activity you looked at some alternate forms of energy which can be used to solve the energy crisis. As a responsible citizen you will need to make educated decisions when you are given choices as scientific and technological advances are made. On the one hand, you try to make the most economical choice and on the other hand, you try to preserve a healthy environment. The best choice will involve a balance of the two among other factors you will have to consider. In the next activity you will look at risk assessment for the use of these alternate resources.

ACTIVITY

3 Energy and Risks



CANADIAN NUCLEAR ASSOCIATION

What would your reaction be if the government authorities decided that a site close to the community where you live was going to be used to build a nuclear power plant? How do you think the people in your community would respond? Chances are most people would be upset and protest the plan.

Why is this so? How have people formed the opinion that living near a nuclear power plant is not safe? These decisions are probably a result of **perceptions** people have made, based on media reports of past events. They may feel that a nuclear plant poses too much of a risk to their community.

perceptions –
opinions formed
by an observer

What is a risk? Do you think you lead a risky life? This activity will explore these questions and others dealing with risk. Then you will apply the concepts studied to the idea of nuclear energy as a risk.

1. As an introduction to the concept of risk and risk assessment, you will be watching a video dealing with this topic. First though, to get you thinking about risks, answer the following survey questions. Don't be afraid to answer the way you feel – there are no definite right or wrong answers to these questions.

- a. Almost every action involves some danger.

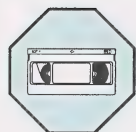
State what it means to you to describe something as “risky”.

- b. Based on your answer to 1.a., suggest how you would try to measure the risk attached to an activity and represent it as a number.
- c. Can you think of any activities that are completely free of any risk?
- d. Rank the following nine activities from most risky (1) to least risky (9) assuming that you engage in the activity.

- Using electrical appliances around the home ()
- Eating..... ()
- Bicycling..... ()
- Smoking..... ()
- Taking a bus trip..... ()
- Playing hockey..... ()
- Driving a motorcycle..... ()
- Swimming..... ()
- Driving a car..... ()

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Check your answers by turning to the Appendix, Section 3: Activity 3.



2. To see how other students tackle similar questions, view the video *How Safe Is Enough?* Preview the following questions before watching the video to get an idea of which concepts are important. You may choose to answer the questions while you watch the video.

- a. How did the teacher suggest that the relative risk of activities be compared at the beginning of the video?
- b. How were risks compared for the activities considered on the monitor?
- c. Why did the students tend to misjudge the risk involved in the activities they were shown?
- d. Information is required to judge the level of risk in an activity. What else determines how people finally evaluate the risk involved?
- e. According to the video, what equation describes how risk can be estimated in order to predict future occurrences?

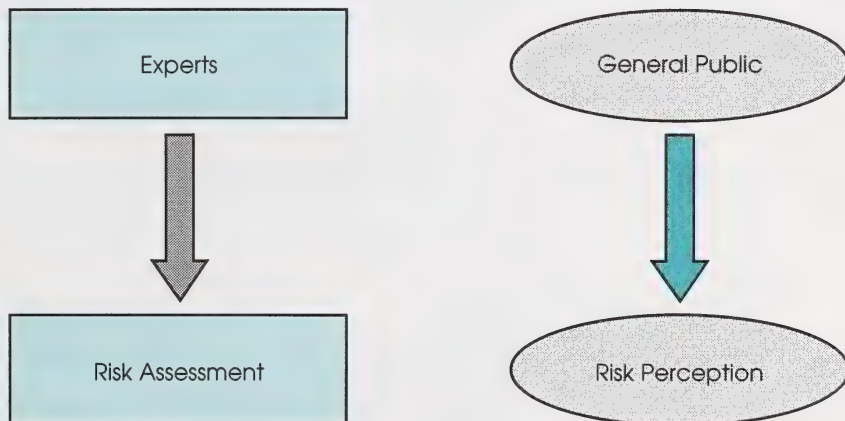
- f. In addition to the level of risk involved, what other information about the activity should be considered?
- g. i. What are three major steps necessary to form a reasonable evaluation of the best way to accomplish a task?
- ii. What is the name of this method of analysis?

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Check your answers by turning to the Appendix, Section 3: Activity 3.

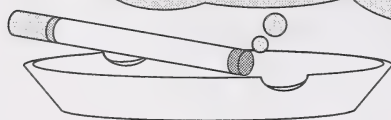


The preceding survey and exercise have pointed out the importance of information in making a decision about the risks and benefits of any activity or issue. You have also seen that the most informed decision would be based on not only expert advice, but the perceptions of the public as well.



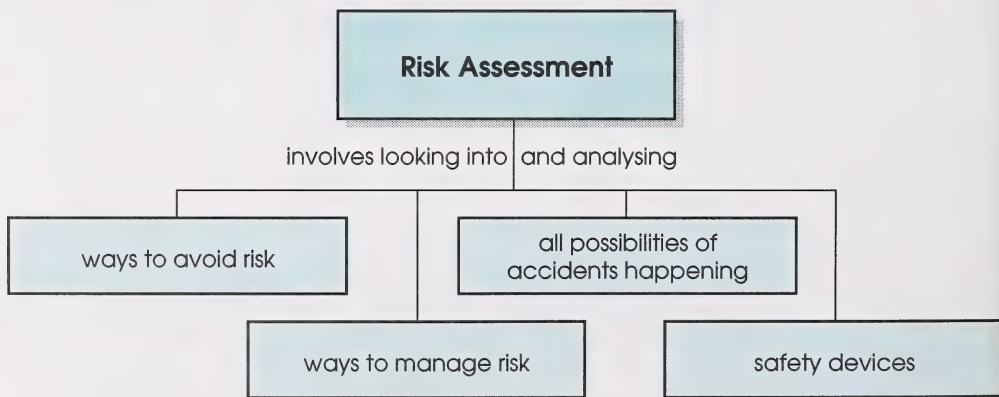
When experts in the field of risk assessment examine the risks involved in a particular activity, their assessments are based on probability and statistics. Statistics is the language of risk assessment. As an example, consider the following statistics which assess the risks from smoking cigarettes.

- Every cigarette that you smoke takes 5 min off your life.
- Thirty percent of all cancers are attributable to cigarette smoking.
- Every cigarette that you smoke increases your chance of death by a factor of 1 in 1.4 million.
- Smoking one pack of cigarettes a day for one year has an associated mortality rate of 3600 deaths in 1 million people.
- People who smoke a pack a day for 50 y will, on average, shorten their life span by 3.5 y.



3. Show that the first and last statistics are consistent with each other by doing the necessary calculations. Note that there are twenty-five cigarettes in one pack.
4. If you sat down and quoted these statistics to a person who smoked one pack of cigarettes a day, what would the response likely be? Would more statistics help?

Check your answers by turning to the Appendix, Section 3: Activity 3.



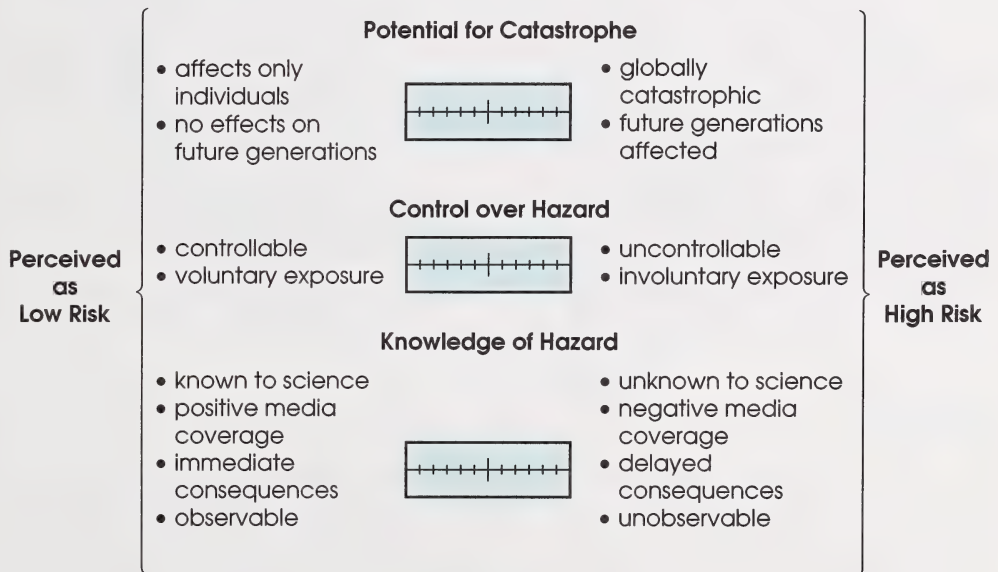
The general public uses a different set of strategies for determining risk. Because their strategies are not based on detailed statistical analysis, the result is referred to as a risk perception rather than a risk assessment.

What criteria do people use in forming a perception of risk? Psychologists have conducted a number of studies to answer this question. Although the detailed answers that people give will vary from hazard to hazard and from one observer to the next, there are trends in the criteria used to form a perception of risk.

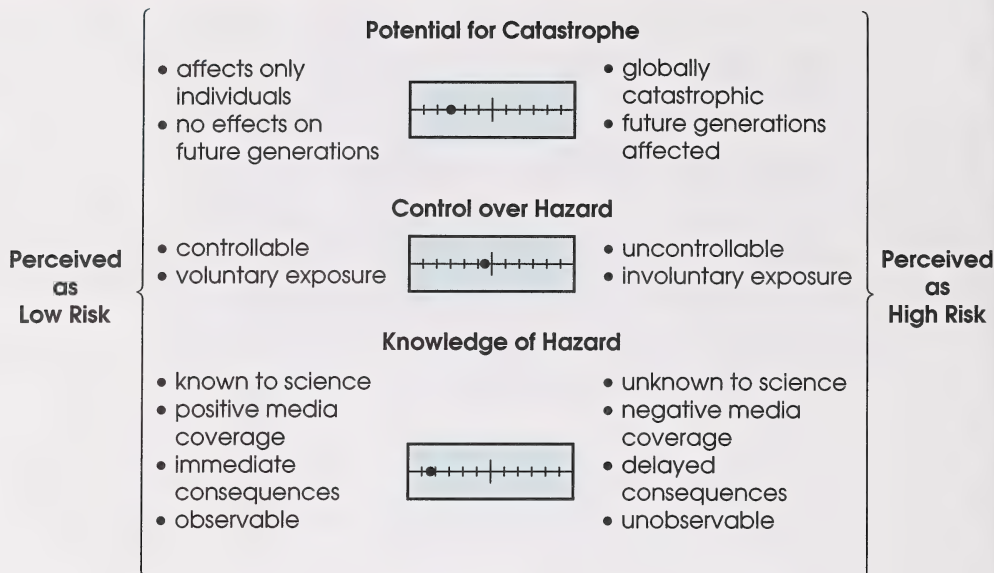
Factors Most Often Used to Form a Risk Perception

- **Potential for Catastrophe:** If the potential exists for killing a large number of people in a very short time, or if the possibility exists for harming future generations, the hazard is perceived to be a high risk.
- **Degree of Control:** If the individual feels that he or she has little control over the hazard, the hazard is perceived to be a high risk.
- **Knowledge:** If the only knowledge that an individual has of a hazard comes from the media (which tends to focus on threats to health and mishaps), or if the individual feels that the hazard is new, undetectable, and unknown to science, the hazard is perceived to be a high risk.

One way to communicate a risk perception using these factors is to put each factor on a continuum, with the extreme points of view at each end.



By referring to these factors, it is possible to speculate why the general public judges some things to be of greater risk than others. For example, consider the perception of risk that most people have towards motor vehicles. The following continuum represents why most people regard motor vehicles as a relatively safe form of travel.



Since most motor vehicle accidents involve individuals and have no effect on future generations, the potential for catastrophe is considered low. The matter of control over the hazard may at first seem high because you choose to be in the vehicle and you may even be driving. However, the actions of other drivers add a level of uncontrollability. Virtually everyone has had first-hand experiences with cars. Media coverage is mixed, with positive coverage (car commercials) and negative coverage (accident reports). The knowledge of the hazard tends to favour a perception of low risk.

You can see why motor vehicles might be judged as having a low to moderate risk. However, this perception would not match the numerical risk assessment by the experts who have determined motor vehicles to be among the top three causes of death in Canada. Depending on how the study is done, details will vary, but it is recognized that motor vehicles, cigarette smoking, and the consumption of alcohol are leading causes of death in Canada.

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☒ F. Evaluating

5. Using the previous example as a guide, use the continuums to determine how you think most people would rate non-nuclear electric generating stations as hazards. Support your answer by explaining each rating. What overall risk might be perceived by the general public? Pay particular attention to the science skill involved.

As with the smoking case, the experts' numerical risk assessment of hydroelectric stations does not agree with the public perception of risk. Whereas the conventional nature of generating electricity (using known technology) may give people the perception that it is relatively safe, in fact it ranks behind only motor vehicles, cigarette smoking, alcohol consumption, and handguns as the fifth largest cause of death in Canada.

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☒ F. Evaluating

6. Use the previous continuums as guides to determine how you think most people would rate nuclear power plants. Support your answer by explaining your rating. Conclude by speculating on the overall risk perceived by the general public. Pay particular attention to the science skill involved.

Check your answers by turning to the Appendix, Section 3: Activity 3.



Experts

Right?

Wrong?

Disagree?

Agree?

Public



Nuclear power is the ultimate example to illustrate the difference in opinion between experts and the general public. From the public's point of view, nuclear power plants have been portrayed as being linked to nuclear weapons and global catastrophe. Mental images of large numbers of people dying, and future generations being adversely affected easily come to mind. In addition, fear is generated because people have the perception that an accident would be uncontrollable, causing thousands of people to be exposed. Finally, radiation is perceived as being unobservable and having many consequences that are still unknown to science. The end result is that many people would judge nuclear power to be one of the top hazards to the citizens of Canada.

In sharp contrast, the experts would say that the probability of death from living a lifetime next to a nuclear power plant is the same as driving 120 km in an automobile. Think about what this statistic is saying: it is safer to live a lifetime beside a nuclear power plant than it is to drive from Calgary to Red Deer (145 km)! Statistically, the probabilities of death are so low that the experts would not even rate nuclear power within the top twenty causes of death in Canada. Yet in the minds of some people, the overwhelming dread of a large-scale nuclear accident renders all statistics meaningless, no matter how low the calculated probability is.

Many people think that nuclear power is just the first in a series of new technologies that will cause the general public and experts to be at odds when it comes to determining risks. It is important for both the experts and the general public to reach common ground when it comes to the management of risk.

7. How can the situation of the experts and the general public being at odds be resolved? List some concrete answers that would help.

Check your answers by turning to the Appendix, Section 3: Activity 3.

Making an Informed Decision

Your role as a decision maker begins right now. You are going to make an informed decision relating to nuclear power and risk.

You will be given the opportunity to choose one of two topics and you will be asked to make an informed decision on the issue. There are no right or wrong answers, but you must adopt a concrete position. The focus is not on your choice, but on how well you support your choice with clear reasoning that is supported by examples. To help you with this process, you will be asked questions that will help you identify important pieces of information and organize your thoughts. Several sources will be given to you as background information.

At the end of this activity you will be asked which of the following opinions you support. You must choose one of these opinions:

Opinion A

A nuclear generating station should not be considered as a way to generate electricity in Alberta in the next twenty years.

Opinion B

A nuclear generating station should be considered as a way to generate electricity in Alberta in the next twenty years.

You will be referring to a number of newspaper articles. These resources can be found at the end of the module Appendix. Before you read each article, familiarize yourself with the applicable questions.

Read the article "Reactor Proposal Draws Ire" in the Appendix and then answer the next two questions.

8. Describe the point of view of the director of the Environment Centre of Alberta.
9. Describe the point of view of the spokesman for Saskatchewan Power.

Read the article "Nuclear Reactor Option Defended" in the Appendix; then answer the following questions.

10. Why does the University of Calgary physics professor consider a nuclear reactor an environmental advancement for Saskatchewan? Explain fully.
11. What are the arguments for and against converting Alberta's coal-fired electric power plants to natural gas?



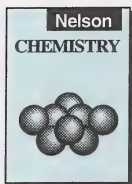
DAVE MORRIS

Coal-fired plants produce about 85 percent of Alberta's electricity because coal is inexpensive and accessible. Alberta has about 60 percent of Canada's proven coal reserves.

Read the article "Alberta Wary of Saskatchewan Nuclear Project" in the Appendix. Answer the next two questions.

12. According to the Alberta Environment Minister, what are the recommended methods for generating electrical power in the three prairie provinces?

13. Compare the comments of the Alberta Environment Minister to the environmental concerns of the University of Calgary physics professor in the previous article.



Read the article titled "The Nuclear Power Alternative" on page 338 of your textbook. Then answer the next question.

14. a. According to the information provided, what are the overall advantages of generating electricity from nuclear power?
- b. What are the disadvantages of generating electricity from nuclear power?
- c. What is the final evaluation made by the article regarding the use of nuclear energy?

Check your answers by turning to the Appendix, Section 3: Activity 3.

Read the article "Use of Nuclear Reactors to Extract Heavy Oil Studied" in the Appendix. Then answer the next question.

15. What role could a nuclear reactor play in helping to extract heavy oil from tar sands?

Read the editorial "A Nuclear Alberta?" in the Appendix. Then answer the following questions.



AOSTRA

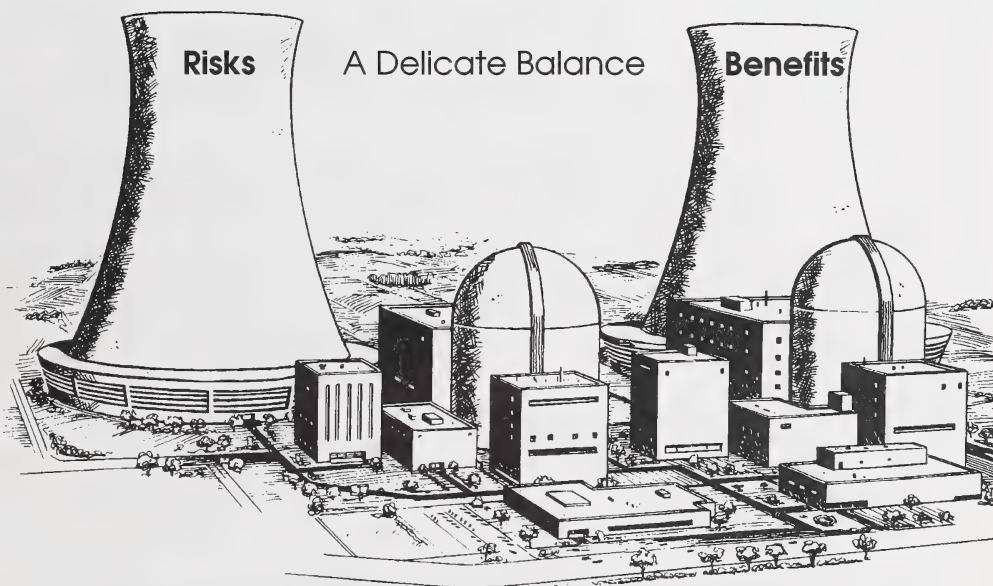
16. Earlier you read an article that described the possibility of a nuclear power plant in Saskatchewan. What reason does the editor give for the arrangement between AECL and the Saskatchewan government falling through?
17. The author of the editorial mentions the nuclear accidents at Three Mile Island and Chernobyl and a leak in a plant near St. Petersburg. The possibility of nuclear meltdown and the release of nuclear wastes into the environment was also mentioned by the director of the Environment Centre for Alberta and the Transportation and Utilities Minister.

In the article "Nuclear Reactor Option Defended", a physics professor from the University of Calgary discusses the possibility of a Chernobyl-type accident in a CANDU reactor. What is the professor's appraisal of this probability?

18. Return to the two opinions (A and B) expressed at the beginning of Making an Informed Decision in this activity. Choose **one** of these opinions and support it by addressing each of the following specific items in your essay answer.

- What is your personal perception of the risks for nuclear power?
- Explain what your perception of risk is based on. Be specific.
- Explain how the information presented in these articles supports your perceptions of the risks involved. Be specific.
- Conclude by explaining which opinion you prefer. Support your answer.

Check your answers by turning to the Appendix, Section 3: Activity 3.

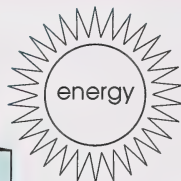
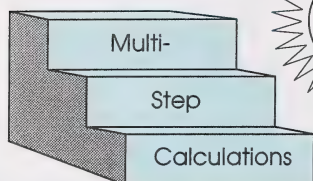


As technological advances are made, you will need to make choices. Your choices must be made with an open mind and be based on correct information. Experts and the general public must respect each other's views. It is the responsibility of the experts to give correct information to the public and the public must make the effort to inform themselves with the knowledge required to arrive at a decision for the issue at hand.

ACTIVITY

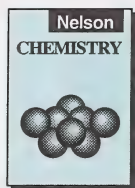
4

The Ultimate Energy Question



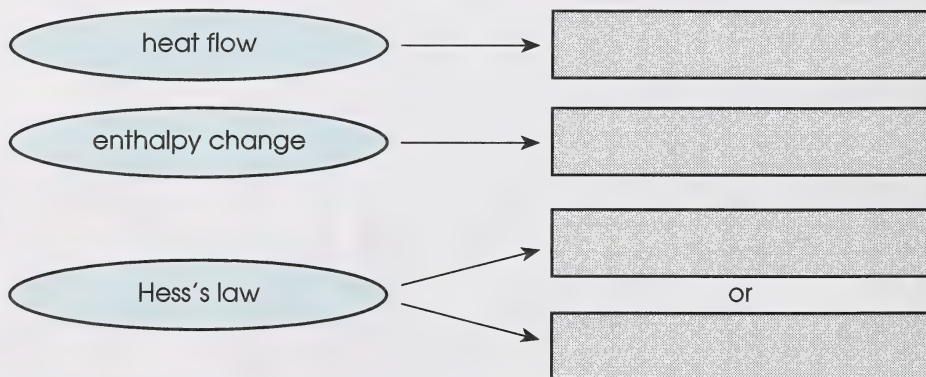
You have seen a great variety of energy problems and questions as you have worked through Modules 1 and 2. This activity gives you a chance to tie together all the knowledge you have gained from the many different questions and concepts studied.

Read the introduction to the section Multi-Step Calculations on page 334 of your textbook to briefly review some of the concepts you have studied.

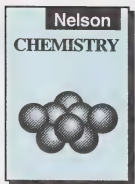


1. Create a chart similar to the following. Indicate the formulas required.

Energy Change Equations



Check your answers by turning to the Appendix, Section 3: Activity 4.



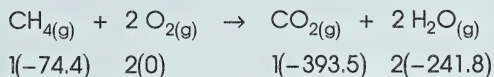
There are a variety of ways that energy calculations can be constructed. You have actually worked with most of them already. Examine the examples on pages 335-336 of *Nelson Chemistry*; then work through the following example.

Example

What mass of methane in a natural gas stove would be required to burn completely to heat 250 mL of water from 22.5°C to 92.0°C? (Assume no loss of heat to the surroundings.)

Step 1

Write out the chemical equation for the combustion of methane and calculate the enthalpy change for this reaction.



$$\begin{aligned} \Delta H^\circ_r &= \sum nH^\circ_{fp} - \sum nH^\circ_{fr} \\ &= \left(1 \text{ mol} \times \frac{-393.5 \text{ kJ}}{\text{mol}} + 2 \text{ mol} \times \frac{-241.8 \text{ kJ}}{\text{mol}} \right) - \left(1 \text{ mol} \times \frac{-74.4 \text{ kJ}}{\text{mol}} + 2 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) \\ &= -802.7 \text{ kJ} \end{aligned}$$

Step 2

Calculate the molar enthalpy of combustion for methane.

$$\begin{aligned} H^\circ_r &= \frac{\Delta H^\circ_r}{n} \\ &= \frac{-802.7 \text{ kJ}}{1 \text{ mol}} \\ &= -802.7 \text{ kJ/mol} \end{aligned}$$

Step 3

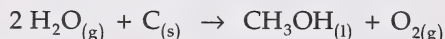
Calculate the mass of methane required by equating the heat released by the methane combustion to the heat gained by the water.

$$\begin{aligned} \Delta H_r &= q \\ \left(\begin{array}{c} \text{methane} \\ \text{combustion} \end{array} \right) & \left(\begin{array}{c} \text{water} \end{array} \right) \\ nH_r &= mc\Delta t \\ m \times \frac{1 \text{ mol}}{16.05 \text{ g}} \times \frac{802.7 \text{ kJ}}{\text{mol}} &= 0.250 \text{ kg} \times \frac{4.19 \text{ kJ}}{\text{kg} \cdot ^\circ\text{C}} \times (92.0 - 22.5)^\circ\text{C} \\ m &= \frac{72.801 \text{ kJ} (16.05 \text{ g})}{802.7 \text{ kJ} (1 \text{ mol})} \\ &= 1.46 \text{ g} \quad \text{The mass of methane required is 1.46 g.} \end{aligned}$$

Note: In this example, mass was solved as the variable. You could have solved for moles (n) first, and then converted to mass as a separate step.

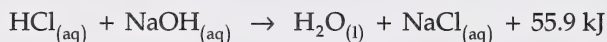
The best way to gain confidence in solving energy problems is through a lot of practice. You will be given several different types of problems to work on in the following questions.

2. Steam is passed over carbon to produce methanol and oxygen. The chemical equation which represents this reaction is as follows:

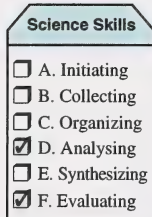
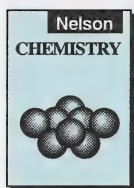


Which combination of energy formulas or equations would you have to use in order to determine the mass of carbon needed to react with steam to produce 832 kJ of heat energy? (You do not have to solve the problem.)

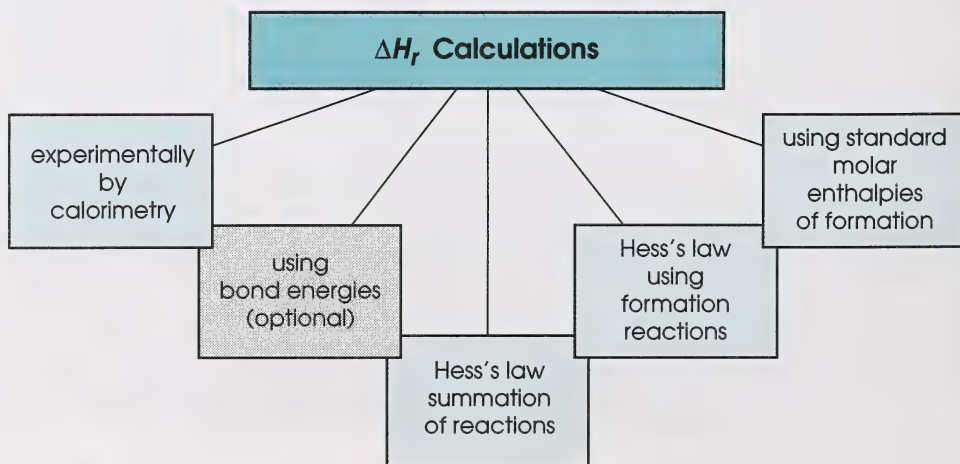
3. Hydrochloric acid undergoes a neutralization reaction with aqueous sodium hydroxide according to the following equation:



Determine the volume of 0.200 mol/L acid required to react completely with the sodium hydroxide solution to produce 95.0 kJ of heat.



4. Complete the analysis and evaluation required in Lab Exercise 11H: H_c by Four Methods on page 343 of your textbook. Pay particular attention to the applied science skills.
- Complete the analysis using calorimetry methods, Hess's law using formation equations, and molar enthalpies of formation. You are not required to solve using bond energies.
 - Evaluate the methods used.



- A mass of 1.50 g of ethanol was burned in the bomb of a calorimeter containing 200 mL of water at 25.0°C. Assuming that liquid water is produced in the reaction along with carbon dioxide gas, what would be the final temperature of water in the calorimeter?
- The combustion of 1.00 g of coke ($C_{(s)}$) gives off 32.8 kJ of heat. Determine the mass of coke required to heat 2.00 L of water from 25.0°C to 95.0°C.

Check your answers by turning to the Appendix, Section 3: Activity 4.

Multi-step energy problems require a systematic approach. Writing down the steps before working with actual numbers can help you think the problem through.

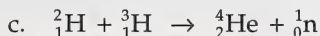
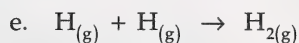
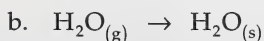
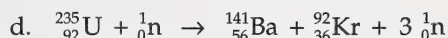
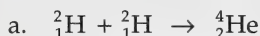
Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

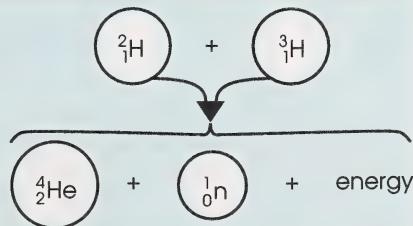
Extra Help

Nuclear reactions involve changes in the nucleus of an atom. Bonds are broken and made between particles such as protons and neutrons.

- Which of the following reactions represent a nuclear change?



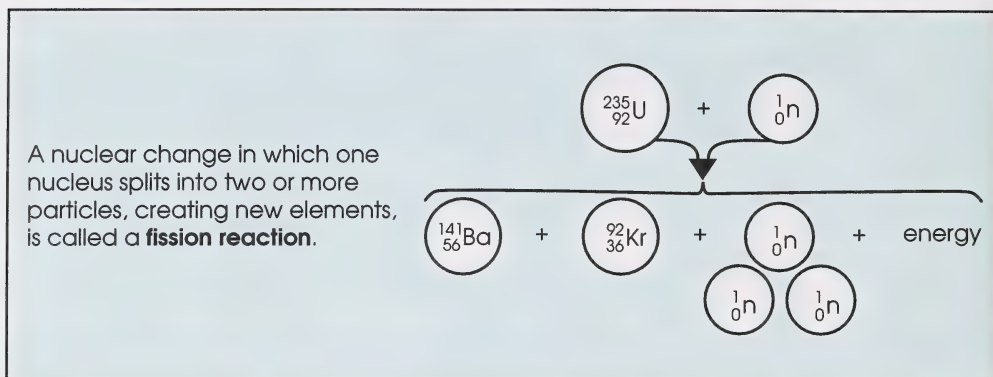
A nuclear change in which two or more small atomic nuclei join to form a single nucleus is called a **fusion reaction**.



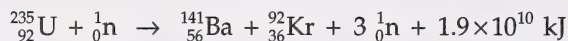
2. The fusion of hydrogen, which might be used in fusion reactors, can be represented as a nuclear change according to the following equation:



Draw a potential energy diagram to represent this change.



3. You are given the following equation:



What mass of ${}^{92}_{36}\text{Kr}$ would be formed through this reaction in the production of $2.6 \times 10^9 \text{ kJ}$ of energy?

4. a. Construct a chart in your notebook using the headings outlined. You will need to adjust the size of your chart according to the length of your answers. Complete the chart to summarize the key ideas from this module.

COMPARING RISK ASSESSMENT TO RISK PERCEPTION		
	Risk Assessment	Risk Perception
Who does it?		
What strategies are used?		
What is the outcome of this process?		

- b. Refer to your answer for part a. to explain why the experts and the general public sometimes have such different opinions about risk.

5. In order to determine the molar heat (enthalpy) of formation of propanol ($\text{C}_3\text{H}_7\text{OH}_{(l)}$), a sample of the alcohol was completely burned in a bomb calorimeter to produce carbon dioxide and water. The following data were collected:

Volume of water in calorimeter	750 mL
Initial temperature of water	20.1°C
Final temperature of water	38.0°C
Mass of propanol burned	1.67 g

A student came up with the following steps to answer the problem. Write the formula equation(s) you will use to solve each step. (Step d. has no equation.) Then, arrange them in the correct order.

- Calculate the molar heat of combustion for propanol.
- Calculate the molar heat of formation of propanol.
- Calculate the heat gained by the water in the calorimeter.
- Write a balanced equation for the reaction.
- Calculate the ΔH_r for the chemical reaction.

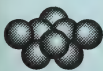
Check your answers by turning to the Appendix, Section 3: Extra Help.

If you would like further practice in working with the concepts presented in this section, answer any of questions 10, 11, 19, 26, and 27 on pages 340-342 of your textbook. The answers to these questions can be found on pages 513-514 of *Nelson Chemistry*.

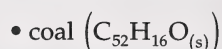
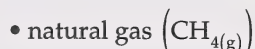
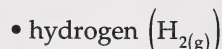
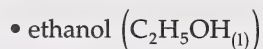
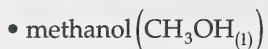
Enrichment

Do any **one** of the following.

- Design a questionnaire you could give to the public to assess the risk perception of the general public towards nuclear power plants as an energy source. (**Hint:** Use the factors involved in forming risk perceptions discussed in this module.)
- The automobile industry across the world has been testing automobiles fuelled by hydrogen. If you had the option, which automobile would you choose, one powered by hydrogen gas or one using gasoline as fuel? Give reasons to support your answer.



3. Make a table comparing advantages, disadvantages, and energy released per gram of the fuel for each of the following fuels:



Check your answers by turning to the Appendix, Section 3: Enrichment.

Conclusion

Nuclear reactions involve very large energy changes. In the 1970s scientists thought that this energy could be used to solve the energy crisis to some degree, and design work on several nuclear plants was started in different countries. However, as public awareness of the hazards from such plants increased, nuclear plant production was scaled down. As the quest for the fuel of the next century continues, you will be required to make informed decisions based on the risks and benefits to society.

15

Section 3 Assignment: Energy Alternatives and Society

Review the Evaluation information found in the introductory pages of this module.

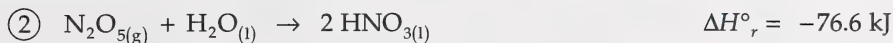
It is important to number and clearly identify each page with the following information at the top:

Chemistry 30 – Module 2 Section 3 Assignment Page # Name and ID#

Be sure to write legibly. Leave a wide left margin and number all of your pages.

1. A student wished to determine the molar heat (enthalpy) of formation for sodium sulphide, $\text{Na}_2\text{S}_{(s)}$. The student designed an investigation where 11.4 g of hydrogen sulphide gas, $\text{H}_2\text{S}_{(g)}$, was completely reacted with solid sodium hydroxide in a bomb calorimeter producing solid sodium sulphide and liquid water. The 250 mL of water in the calorimeter changed in temperature from 23.2°C to 43.8°C. Assuming only the calorimeter water gained the heat energy, calculate the molar heat of formation for sodium sulphide. Show your work neatly and completely. (5 marks)

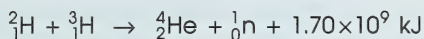
2. You are given the following information equations:



Calculate the ΔH°_r for the following reaction: $2 \text{N}_{2(g)} + 5 \text{O}_{2(g)} \rightarrow 2 \text{N}_2\text{O}_{5(g)}$

Show how you manipulate your information equations to achieve your answer.
(4 marks)

3. Use the following fission and fusion reactions to answer this question.



a. Which substance, ${}^{235}_{92}\text{U}$ or ${}^2_1\text{H}$, is more efficient by releasing more energy per gram reacted? Support your answer with calculations. (3 marks)

b. Choose **one** of the following opinions.

Opinion A

Fission reactors would be better to use than fusion reactors for producing electrical energy.

Opinion B

Fusion reactors would be better to use than fission reactors for producing electrical energy.

Give three reasons for your choice. There are no right or wrong opinions for this question. Your marks will be based on how well you defend your opinion.
(3 marks)

Reproduce the science skills assessment box after your response to this question. Remember to indicate your evaluation of your skill level for each identified science skill. Leave a space for the teacher assessment.

Self: A.	☐	B.	☐	C.	☐	D.	☐	E.	☐	F.	☐
Teacher: A.	☐	B.	☐	C.	☐	D.	☐	E.	☐	F.	☐

MODULE SUMMARY

Through your work in this module, you have discovered various methods of calculating and expressing energy changes. Hess's law has shown you that there are several different ways of achieving the same end result, which allows for more flexibility in solving energy problems. You have also examined different energy alternatives, necessitated by the dwindling supply of fossil fuels and their adverse effects on the environment. The changing energy demands of society and the environment point toward the need for a well-informed population that can completely assess the risks and benefits of old and new energy resources.

25

Final Module Assignment

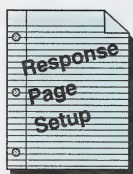
Review the Evaluation information found in the introductory pages of this module.

It is important to number and clearly identify each page with the following information at the top:

Chemistry 30 – Module 2 Final Module Assignment Page # Name and ID#

Be sure to write legibly. Leave a wide left margin and number all of your pages.

Part A: Multiple Choice



Read each question carefully and decide which of the choices best completes the statement or answers the question. Place the number of each question in a vertical column and place your answer (A, B, C, or D) beside each number. Each question is worth one mark. (Total = 5 marks)

1. Use the following information to answer this question.

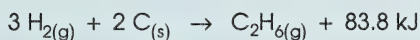
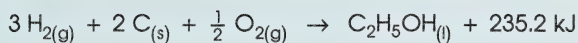
Molar Heat of Formation (kJ/mol) of Halides			
$\text{AgCl}_{(s)}$	-127.0	$\text{NaCl}_{(s)}$	- 411.2
$\text{AgBr}_{(s)}$	-100.4	$\text{NaBr}_{(s)}$	- 361.1
$\text{AgI}_{(s)}$	- 61.8	$\text{NaI}_{(s)}$	- 287.8

A generalization that could be made about these compounds is that

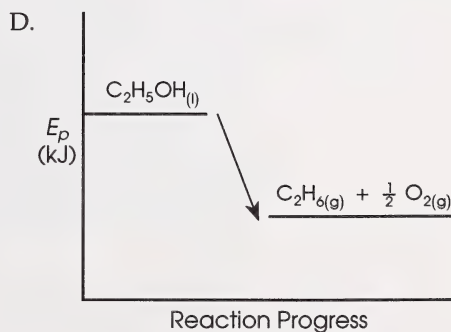
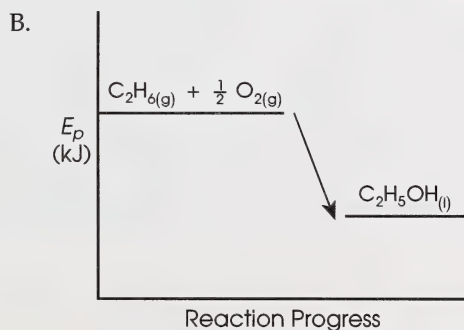
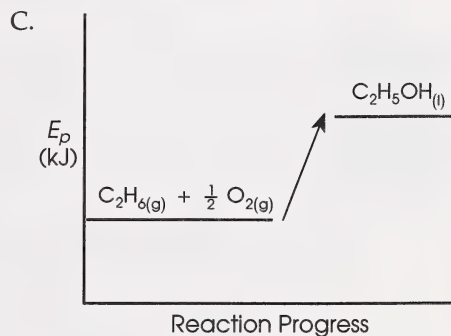
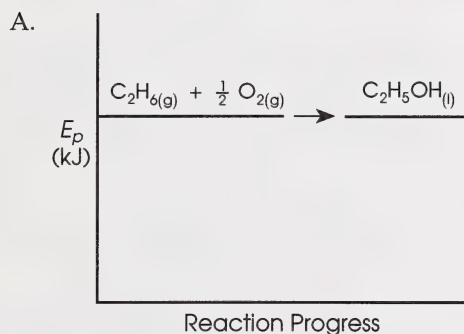
- A. iodine forms stronger bonds than chlorine
- B. iodine compounds are more stable than chlorine compounds
- C. sodium forms stronger bonds with halogens than silver
- D. silver halides are more stable than sodium halides

2. When the heat of combustion of a substance is measured by calorimetry, it is assumed that
- A. as the temperature increases, the rate of reaction increases
 - B. the heat released per mole will depend on the amount of water in the calorimeter
 - C. the heat released per mole will depend on the number of moles of substance burned
 - D. the heat gained by the calorimeter and its contents is equal to the heat released by the substance

3. Use the following information to answer this question.

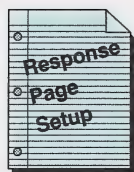


The diagram that represents the reaction $\text{C}_2\text{H}_{6(\text{g})} + \frac{1}{2} \text{O}_{2(\text{g})} \rightarrow \text{C}_2\text{H}_5\text{OH}_{(\text{l})}$ is



4. If $\frac{1}{2} \text{N}_{2(g)} + \text{O}_{2(g)} + 33.8 \text{ kJ} \rightarrow \text{NO}_{2(g)}$, the heat required for the formation of 2.50 mol of $\text{NO}_{2(g)}$ is
- 84.5 kJ
 - 67.6 kJ
 - 33.8 kJ
 - 13.5 kJ
5. Which of these involves the greatest energy change?
- $4 \text{U}_{(s)} + 5 \text{O}_{2(g)} \rightarrow 2 \text{U}_2\text{O}_{5(s)}$
 - $\text{U}_2\text{O}_{5(s)} \rightarrow \text{U}_2\text{O}_{5(l)}$
 - ${}^{235}_{92}\text{U} \rightarrow {}^{233}_{90}\text{Th} + 2 {}^1_1\text{H}$
 - $\text{PbO}_{2(s)} \rightarrow \text{Pb}_{(s)} + \text{O}_{2(g)}$

Part B: Numerical Response



Read each question carefully. Record only your final answer by writing it in a four-box unit similar to the following:

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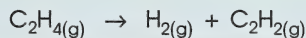
 Enter the first digit of your answer in the left-hand box and leave any unused boxes blank. If a decimal point occurs in your answer, it should occupy its own box.

6. A sample of solid cesium initially at its melting point (28.4°C) is continuously heated. The energy changes that may occur are indicated here:

- The solid warms and thus gains kinetic energy.
- The liquid warms and thus gains potential energy.
- The solid melts and thus gains potential energy.
- The solid melts and thus gains kinetic energy.
- The liquid warms and thus gains kinetic energy.
- The liquid vaporizes and thus gains kinetic energy.
- The liquid vaporizes and thus gains potential energy.
- The gas warms and thus gains potential energy.
- The gas warms and thus gains kinetic energy.

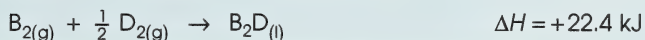
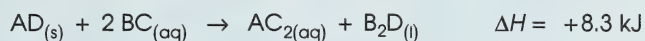
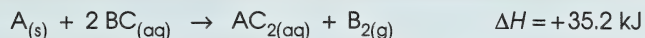
The first four energy changes that would occur, in order, are _____. (Record all four digits in the boxes on your response sheet.) (1 mark)

7. Use the following reaction to answer this question.



The ΔH for this reaction is _____ $\times 10^2$ kJ. (Record your answer to three digits in the boxes on your response sheet.) **(1 mark)**

8. Use the following information equations to answer this question.



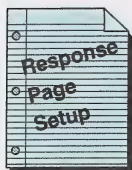
The ΔH for the reaction $\text{A}_{(s)} + \frac{1}{2} \text{D}_{2(g)} \rightarrow \text{AD}_{(s)}$ is _____ kJ. (Record your answer to three digits in the boxes on your response sheet.) **(1 mark)**

9. When heat is applied to a 15.0 g sample of copper metal, the temperature of the copper increases from 23.0°C to 380.0°C. An equal amount of heat is applied to an unknown mass of aluminum and causes the same temperature change. The mass of aluminum is _____ g. (Record your answer to three digits in the boxes on your response sheet.) **(1 mark)**
10. A student completely burned a small candle and found that burning the candle warmed 50 g of water from 20°C to 26°C. If the student were to repeat the experiment using an identical candle and, this time, 150 g of water at 20°C, the expected final temperature of the water would be _____°C. (Record your answer to two digits in the boxes on your response sheet.) **(1 mark)**
11. A student designed a calorimetric experiment to determine the molar heat of solution for ammonium nitrate. After dissolving the ammonium nitrate in the calorimeter water, the student recorded these data:

mass of calorimeter	15.20 g
mass of water and calorimeter	114.80 g
initial temperature of water	23.6°C
final temperature of water	18.5°C
mass of $\text{NH}_4\text{NO}_{3(s)}$	6.68 g

Based on these data, and assuming that only the water absorbed energy, the molar heat of solution for ammonium nitrate is _____ kJ/mol. (Record your answer to three digits in the boxes on your response sheet.) **(1 mark)**

Part C: Written Response

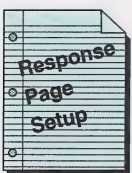


Write your answers neatly and concisely. For full marks, your answers must show all pertinent explanations, calculations, and formulas.

12. Use the following information to answer this question.

Experiment	Substance	Molar Mass	Mass	Mass of Water Heated	Temperature Change of Water
I	a	200.0 g/mol	0.100 g	10.0 kg	75°C
II	b	25.0 g/mol	1.00 g	10.0 g	85°C
III	c	105.0 g/mol	2.00 g	1.00 kg	45°C

Identify which experiment corresponds to a phase change, to a chemical reaction, and to a nuclear reaction. Justify your answer by providing logical reasons and/or specific calculations for **each** identification. (8 marks)



Reproduce the science skills assessment box after your response to this question. Remember to indicate your evaluation of your skill level for each identified science skill. Leave a space for the teacher assessment.

Self: A.	☐	B.	☐	C.	☐	D.	☐	E.	☐	F.	☐
Teacher: A.	☐	B.	☐	C.	☐	D.	☐	E.	☐	F.	☐

13. Explain the three main differences between a risk assessment and a risk perception. (6 marks)

To ensure that all of your work has been completed in a satisfactory manner, check off the items in the following list:

- ☐ Section 1 Assignment has been completed.
- ☐ Section 2 Assignment has been completed.
- ☐ Section 3 Assignment has been completed.
- ☐ The Final Module Assignment has been completed.
- ☐ Your responses are organized and neat, with room for teacher comments.
- ☐ All your response pages are numbered consecutively and identified with this heading.

Chemistry 30 – Module 2 Section # Assignment Page # Name and ID #

Submit **only** your assignment response pages for evaluation.

Appendix



Glossary
Suggested Answers
Article Readings

Glossary

biomass: plant materials

cellular respiration: the controlled oxidation of carbohydrates to release energy in living cells

cellulose: a plant polysaccharide that makes up the walls of plant cells

Hess's law: states that the addition of chemical equations yields a net chemical equation whose enthalpy change is the sum of the individual positive and negative enthalpy changes

isotopes: atoms of the same element with different numbers of neutrons

lignin: a natural polymer that combines with cellulose to form the woody cell walls of plants and the cement between them

nuclear change: a change in the nucleus of an atom which results in the formation of a different type of an atom or atoms with a large release of energy

nuclear fission: a nuclear change involving the splitting of an atomic nucleus into smaller nuclei

nuclear fusion: a nuclear change where smaller nuclei are fused together to make larger nuclei

perceptions: opinions formed by an observer

radiation: energy that travels through space in the form of waves or particles

photosynthesis: the formation of carbohydrates by chlorophyll-containing plants exposed to sunlight

reference point: a chosen, known fixed mark or standard against which an unknown can be measured

thermochemical equations: chemical equations which show an energy change as a part of the equation

Suggested Answers

Section 1: Activity 1

1. Your answers to the questions would be " $q = mc\Delta t$ " and " $\Delta H = nH$."

2.

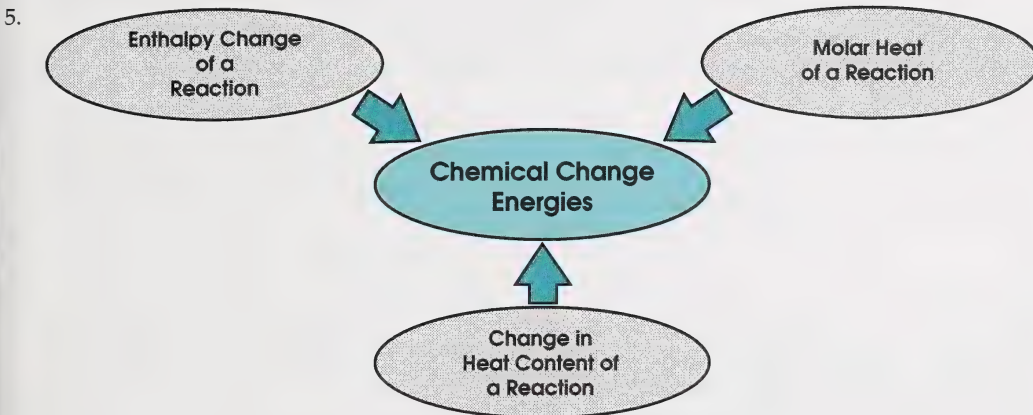
Quantity	Symbol	Unit
Flow of heat	q	J, kJ
Enthalpy change	ΔH	J, kJ
Molar enthalpy	H	J/mol, kJ/mol
Change in temperature	Δt	°C
Specific heat capacity	c	J/g•°C, kJ/kg•°C

3. $\Delta H = nH$

$$\begin{aligned}
 &= 10.0 \text{ g} \times \frac{1 \text{ mol}}{18.02 \text{ g}} \times \frac{6.03 \text{ kJ}}{\text{mol}} \\
 &= 3.35 \text{ kJ} \quad \text{The energy required is 3.35 kJ.}
 \end{aligned}$$

4. $q = mc\Delta t$
 $= 2.50 \text{ kg} \times \frac{4.19 \text{ kJ}}{\text{kg} \cdot ^\circ\text{C}} \times (60.0 - 25.0)^\circ\text{C}$
 $= 367 \text{ kJ}$

The energy required is 367 kJ.



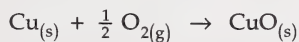
6. The four methods of communicating enthalpy changes are as follows:

- stating the molar enthalpy of a reaction
- describing an enthalpy change for a balanced chemical equation
- including an energy value in a balanced equation
- drawing a potential energy diagram

7. Molar enthalpies are measured by calorimetry. It is important to specify the substance and the reaction being investigated.

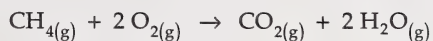
8. a. The expression means that 157.3 kJ of energy is released when one mole of copper(II) oxide is formed from its elements under SATP conditions.

b. The balanced chemical equation is



c. This reaction is called a molar enthalpy of formation reaction because one mole of a compound is produced from its elements in their standard states. (The reaction could also be called a combustion reaction because copper is being burned in the presence of oxygen.)

9. The symbol H°_c represents the standard molar enthalpy of combustion. An example of a reaction that H°_c would apply to is



10.

Symbol	Explanation
H°	represents standard molar enthalpy; measurements recorded at SATP
H	represents molar enthalpy not measured at SATP
H°_r	standard molar enthalpy for a specified reaction

11. a. The experimental design may be as follows:

A metal can calorimeter containing a known quantity of water is heated by a burner containing methanol as a fuel. Record the mass of methanol burned and the maximum temperature change of the water.

b. The two assumptions are as follows:

- The heat lost to the surroundings is insignificant.
- There is complete combustion of the methanol.

c. Your evidence table may look similar to the one following:

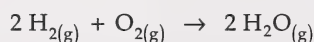
initial temperature of calorimeter water ($^\circ\text{C}$) =	
final temperature of calorimeter water ($^\circ\text{C}$) =	
mass of calorimeter water (g) =	
initial mass of methanol + burner (g) =	
final mass of methanol + burner (g) =	

d. The equation used is

$$\begin{array}{c} nH_c \\ \left(\begin{array}{c} \text{methanol} \\ \text{burning} \end{array} \right) \end{array} = \begin{array}{c} mc\Delta t \\ \left(\begin{array}{c} \text{calorimeter} \\ \text{water} \end{array} \right) \end{array}$$

Section 1: Activity 2

1. The balanced equation for the combustion of hydrogen gas is

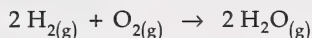


2. The two things required are a molar enthalpy value and a balanced equation.

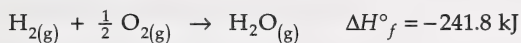
3. The enthalpy change for the reaction is written next to (to the right of) the balanced chemical equation. (See the example on page 317 of *Nelson Chemistry*.)

4. If the reaction is exothermic, the enthalpy value is negative (-). If the reaction is endothermic, the enthalpy value is positive (+).

5. a. The value for the enthalpy change of a reaction has the unit **kJ**. Since this value is written with the chemical equation, you can tell with what number of moles of reactants and products this enthalpy change is associated.
- b. A molar enthalpy value has the unit **kJ/mol**. Since the enthalpy value is always associated with a certain amount of substance involved, a molar enthalpy value needs the *per mole* part of its unit because it is not usually written beside a chemical equation.
6. The balanced equation for the combustion of hydrogen gas from question 1 is as follows:



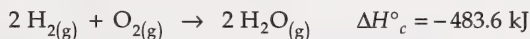
When the preceding equation is balanced for one mole of water, it also represents the molar heat of formation reaction for water vapour (one mole of a substance formed from its elements at SATP). Therefore, the standard molar enthalpy of formation for water vapour, -241.8 kJ/mol , can be applied to this equation.



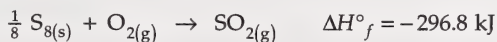
Since the original equation was balanced with whole numbers, and the question asks for the enthalpy change of combustion for hydrogen, the answer would be determined as follows:

$$\begin{aligned} \Delta H^\circ_c &= n \boxed{H^\circ_c} \longleftarrow H^\circ_c (\text{hydrogen}) = H^\circ_f (\text{water vapour}) \\ &\quad \longleftarrow \text{number of moles from equation} \\ &= 2 \cancel{\text{mol}} \times \frac{-241.8 \text{ kJ}}{\cancel{\text{mol}}} \quad \text{is an exact number, so it does not affect the} \\ &\quad \text{significant digits of the answer} \\ &= -483.6 \text{ kJ} \quad \longleftarrow \text{negative sign means exothermic reaction} \end{aligned}$$

This calculated value can then be properly positioned with the original equation.



7. a. From the Standard Molar Enthalpies of Formation table on page 551 of *Nelson Chemistry*, $H^\circ_f (\text{SO}_{2(\text{g})}) = -296.8 \text{ kJ/mol}$. The standard molar enthalpy (heat) of formation equation, then, would be as follows (remember, form one mole of a substance from its elements):



- b. You can find a molar enthalpy value for $\text{SO}_{2(g)}$ from the equation in 7.a. or from the standard molar enthalpy of formation table.

$$\text{From the equation: } H^\circ_f(\text{SO}_2) = \frac{\Delta H^\circ_f(\text{SO}_2)}{1 \text{ mol SO}_2} \quad \text{or,} \quad \text{From the table: } H^\circ_f(\text{SO}_2) = -296.8 \text{ kJ/mol}$$

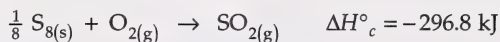
$$= -296.8 \text{ kJ/mol}$$

Now that you know the molar enthalpy value, you can determine the enthalpy change for 1.50 mol $\text{SO}_{2(g)}$.

$$\Delta H = 1.50 \text{ mol} \times \frac{-296.8 \text{ kJ}}{\text{mol}}$$

$$= -445 \text{ kJ}$$

- c. The chemical equation for the combustion of sulphur is the same equation as for the formation of $\text{SO}_{2(g)}$.



Therefore, the enthalpy change for the combustion of 3.20 mol $\text{S}_{8(s)}$ can be found as follows:

Step 1

Find a molar enthalpy value for $\text{S}_{8(s)}$.

$$H^\circ_c(\text{S}_8) = \frac{\Delta H^\circ_c}{n}$$

$$= \frac{-296.8 \text{ kJ}}{\frac{1}{8} \text{ mol}}$$

$$= -2374.4 \text{ kJ/mol} \quad (\text{Keep the same one-decimal place precision.})$$

Step 2

Multiply the molar enthalpy value by the number of moles reacted.

$$\Delta H^\circ_c = \frac{-2374.4 \text{ kJ}}{\text{mol}} \times 3.20 \text{ mol}$$

$$= -7598.08 \text{ kJ}$$

$$= -7.60 \times 10^3 \text{ kJ} \quad (-7.60 \text{ MJ}) \quad (\text{rounded correctly to three significant digits})$$

The enthalpy change for the combustion of 3.20 mol of sulphur is -7.60 MJ .

8. a. **Step 1** Determine the molar enthalpy value for iron ($\text{Fe}_{(s)}$) from the equation.

$$H = \frac{\Delta H}{n}$$

$$= \frac{+468.1 \text{ kJ}}{4 \text{ mol Fe}}$$

$$= +117.0 \text{ kJ/mol Fe}$$

Step 2

Multiply the molar enthalpy value by the amount of iron produced.

$$\Delta H = \frac{+117.0 \text{ kJ}}{\text{mol Fe}} \times \frac{1 \text{ mol Fe}}{55.85 \text{ g}} \times 25.6 \text{ g} \leftarrow \text{Notice that, since a mass value was given instead of moles, an extra step using the molar mass was necessary.}$$

$$= +53.6 \text{ kJ}$$

The enthalpy change is +53.6 kJ.



You should be rounding numbers only in your final answers. Intermediate step answers are shown rounded in this course only for the sake of simpler illustration. The final answers given are from unrounded intermediate values.

b. The process described is endothermic because the enthalpy change is positive.

9. The solution to this problem will be written in steps and in a one-line method.

Steps	One-Line Method
Step 1 Find the molar enthalpy of combustion of benzene. $H_c = \frac{\Delta H_c}{n}$ $= \frac{-8027 \text{ kJ}}{1.28 \text{ mol}}$ $= -6271.1 \text{ kJ/mol}$	$\Delta H_c = \frac{-8027 \text{ kJ}}{1.28 \text{ mol}} \times 2 \text{ mol}$ $= -12.542 \times 10^3 \text{ kJ}$ $= -12.5 \text{ MJ}$ The enthalpy change is -12.5 MJ.
Step 2 Find the enthalpy change for two moles of benzene. $\Delta H_c = \frac{-6271.1 \text{ kJ}}{\text{mol}} \times \boxed{2 \text{ mol}} \leftarrow \text{Remember, an exact number such as a coefficient does not affect the significant digits in the answer.}$ $= -1.2542 \times 10^4 \text{ kJ}$ $= -12.5 \text{ MJ}$ The enthalpy change is -12.5 MJ.	

10. a. The thermochemical equation is



b. The thermochemical equation for the reverse reaction is



- c. The molar enthalpy is -1301 kJ/mol .

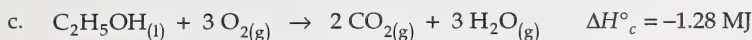
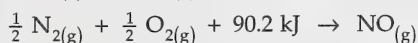
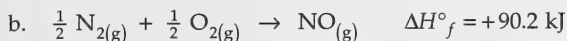
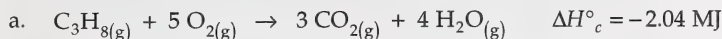
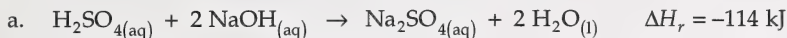
$$\begin{aligned} H_c &= \frac{-2602 \text{ kJ}}{2 \text{ mol}} \\ &= -1301 \text{ kJ/mol} \end{aligned}$$

11. Textbook question 1:

- a. $\text{CH}_3\text{OH}_{(l)} + \frac{3}{2} \text{O}_{2(g)} \rightarrow \text{CO}_{2(g)} + 2 \text{H}_2\text{O}_{(g)} \quad \Delta H^\circ_c = -638.0 \text{ kJ}$
- b. $\text{C}_{(s)} + \frac{1}{4} \text{S}_{8(s)} \rightarrow \text{CS}_{2(l)} \quad \Delta H^\circ_f = +89.0 \text{ kJ}$
- c. $\text{ZnS}_{(s)} + \frac{3}{2} \text{O}_{2(g)} \rightarrow \text{ZnO}_{(s)} + \text{SO}_{2(g)} \quad \Delta H^\circ_c = -441.3 \text{ kJ}$
- d. $\text{Fe}_2\text{O}_{3(s)} \rightarrow \frac{3}{2} \text{O}_{2(g)} + 2 \text{Fe}_{(s)} \quad \Delta H^\circ_{sd} = +824.2 \text{ kJ}$

Textbook question 2:

- a. $H^\circ_c(\text{H}_2) = \frac{\Delta H^\circ_c}{n}$
 $= \frac{-483.6 \text{ kJ}}{2 \text{ mol}}$
 $= -241.8 \text{ kJ/mol}$ The molar enthalpy of combustion for $\text{H}_{2(g)}$ is -241.8 kJ/mol .
- b. $H^\circ_c(\text{NH}_3) = \frac{\Delta H^\circ_c}{n}$
 $= \frac{-1134.4 \text{ kJ}}{4 \text{ mol}}$
 $= -283.6 \text{ kJ/mol}$ The molar enthalpy of combustion for $\text{NH}_{3(g)}$ is -283.6 kJ/mol .
- c. $H^\circ_c(\text{N}_2) = \frac{\Delta H^\circ_c}{n}$
 $= \frac{+163.2 \text{ kJ}}{2 \text{ mol}}$
 $= +81.6 \text{ kJ/mol}$ The molar enthalpy of combustion for $\text{N}_{2(g)}$ is $+81.6 \text{ kJ/mol}$.
- d. $H^\circ_c(\text{Fe}) = \frac{\Delta H^\circ_c}{n}$
 $= \frac{-1118.4 \text{ kJ}}{3 \text{ mol}}$
 $= -372.8 \text{ kJ/mol}$ The molar enthalpy of combustion for $\text{Fe}_{(s)}$ is -372.8 kJ/mol .

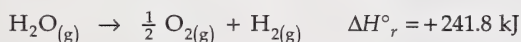
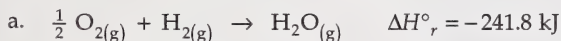
Textbook question 3:**Textbook question 4:**

$$\begin{aligned} \text{b. } H_r(\text{H}_2\text{SO}_4) &= \frac{\Delta H_r}{n} \\ &= \frac{-114 \text{ kJ}}{1 \text{ mol}} \\ &= -114 \text{ kJ/mol} \end{aligned}$$

The molar enthalpy of neutralization for sulphuric acid is -114 kJ/mol .

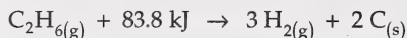
$$\begin{aligned} \text{c. } H_r(\text{NaOH}) &= \frac{\Delta H_r}{n} \\ &= \frac{-114 \text{ kJ}}{2 \text{ mol}} \\ &= -57 \text{ kJ/mol} \end{aligned}$$

The molar enthalpy of neutralization for sodium hydroxide is -57 kJ/mol .

Textbook question 5:

- b. The magnitude of the enthalpy change is the same but the signs (+ and -) are opposite. This would apply to all pairs of reversible reactions.

12. a. The decomposition reaction would be as follows:



$$\begin{aligned} H_d(\text{C}_2\text{H}_6) &= \frac{\Delta H_d}{n} \\ &= \frac{+83.8 \text{ kJ}}{1 \text{ mol C}_2\text{H}_6} \\ &= +83.8 \text{ kJ/mol C}_2\text{H}_6 \end{aligned}$$

$$\begin{aligned} \Delta H &= \frac{+83.8 \text{ kJ}}{1 \text{ mol C}_2\text{H}_6} \times \frac{1 \text{ mol C}_2\text{H}_6}{30.08 \text{ g}} \times 62.3 \text{ g} \\ &= +174 \text{ kJ} \quad \text{The enthalpy change would be } +174 \text{ kJ.} \end{aligned}$$

- b. The reaction equation given represents a molar enthalpy (molar heat) of formation equation for $\text{C}_2\text{H}_{6(g)}$ because one mole of $\text{C}_2\text{H}_{6(g)}$ is being formed from its elements.

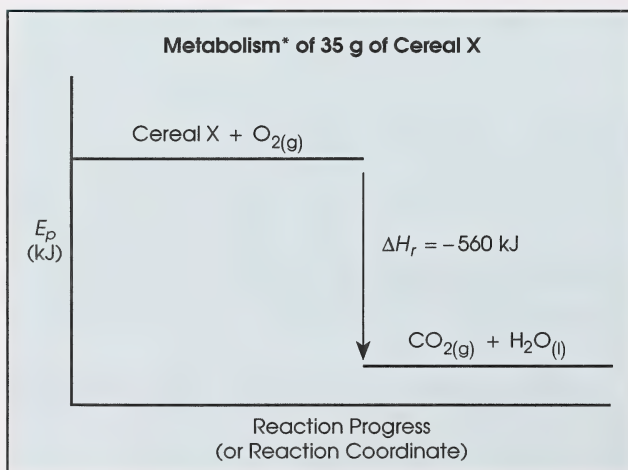
13. a. The thermochemical equation for the formation of $\text{MgO}_{(s)}$ would be



$$\begin{aligned} \text{b. } \Delta H &= \frac{-601.6 \text{ kJ}}{1 \text{ mol MgO}} \times \frac{1 \text{ mol MgO}}{40.31 \text{ g}} \times 5.00 \text{ g} \\ &= -74.6 \text{ kJ} \quad \text{Forming } 5.00 \text{ g of MgO}_{(s)} \text{ would involve an enthalpy change of } -74.6 \text{ kJ.} \end{aligned}$$

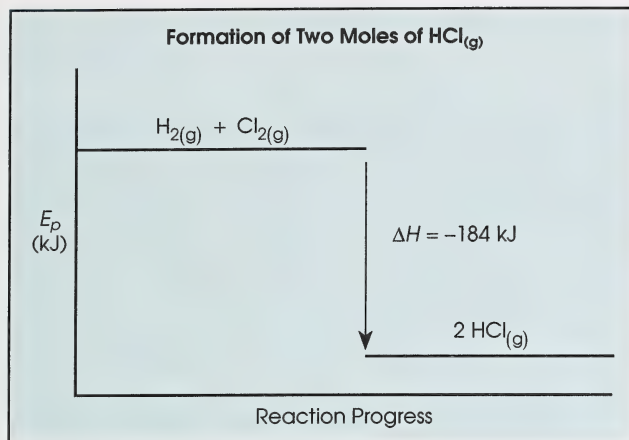
Section 1: Activity 3

1.



***Note:** The metabolism of cereal in the body is somewhat more complicated than depicted here. The metabolic process has been simplified for the sake of comparison to combustion reactions.

2. a.

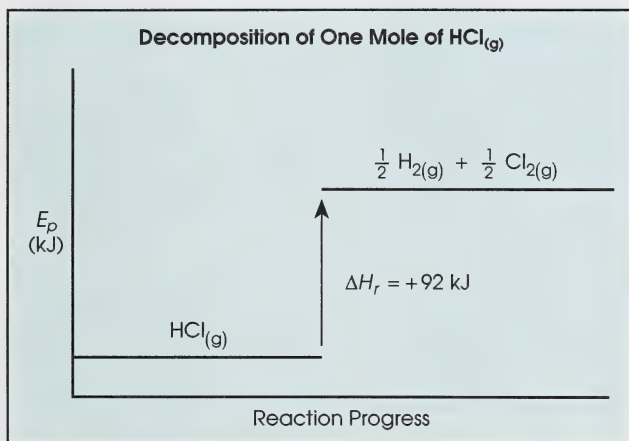


$$\begin{aligned}\Delta H &= +436 \text{ kJ} + 244 \text{ kJ} - 864 \text{ kJ} \\ &= -184 \text{ kJ}\end{aligned}$$

- b. Since the potential energy diagram shows an enthalpy change of -184 kJ for 2 mol of $\text{HCl}_{(g)}$ formed, the molar heat of formation for $\text{HCl}_{(g)}$ would be -92 kJ/mol .

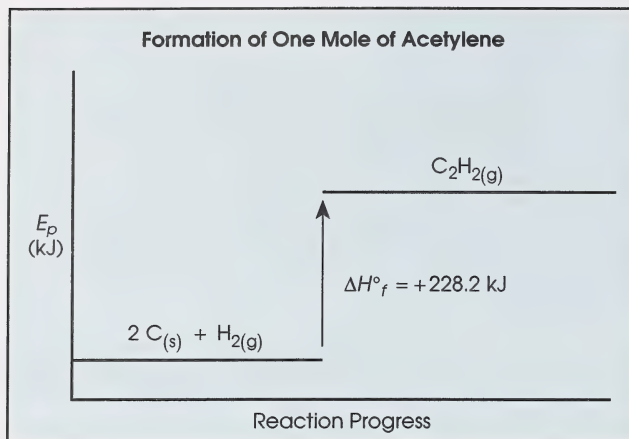
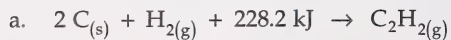
$$\begin{aligned}H_f &= \frac{-184 \text{ kJ}}{2 \text{ mol}} \\ &= -92 \text{ kJ/mol}\end{aligned}$$

c.

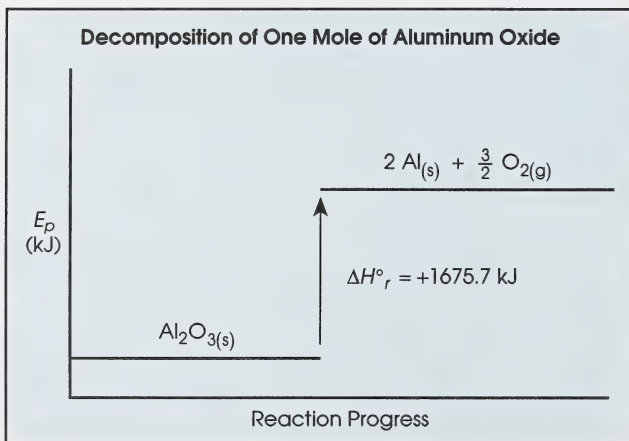
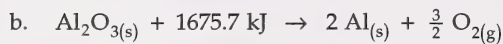


- d. i. Forming bonds involves an exothermic energy change.
ii. Breaking bonds involves an endothermic energy change.

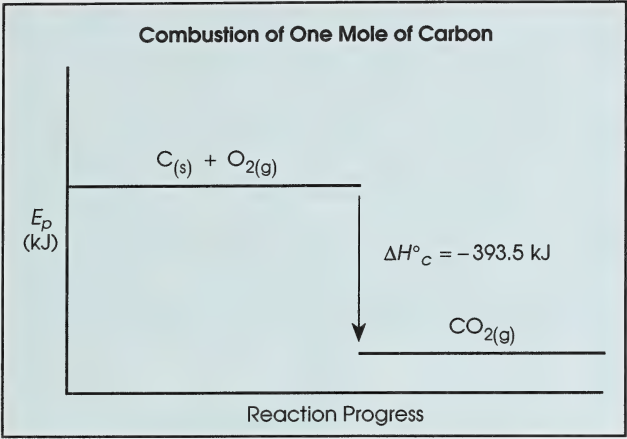
3. Textbook question 6:



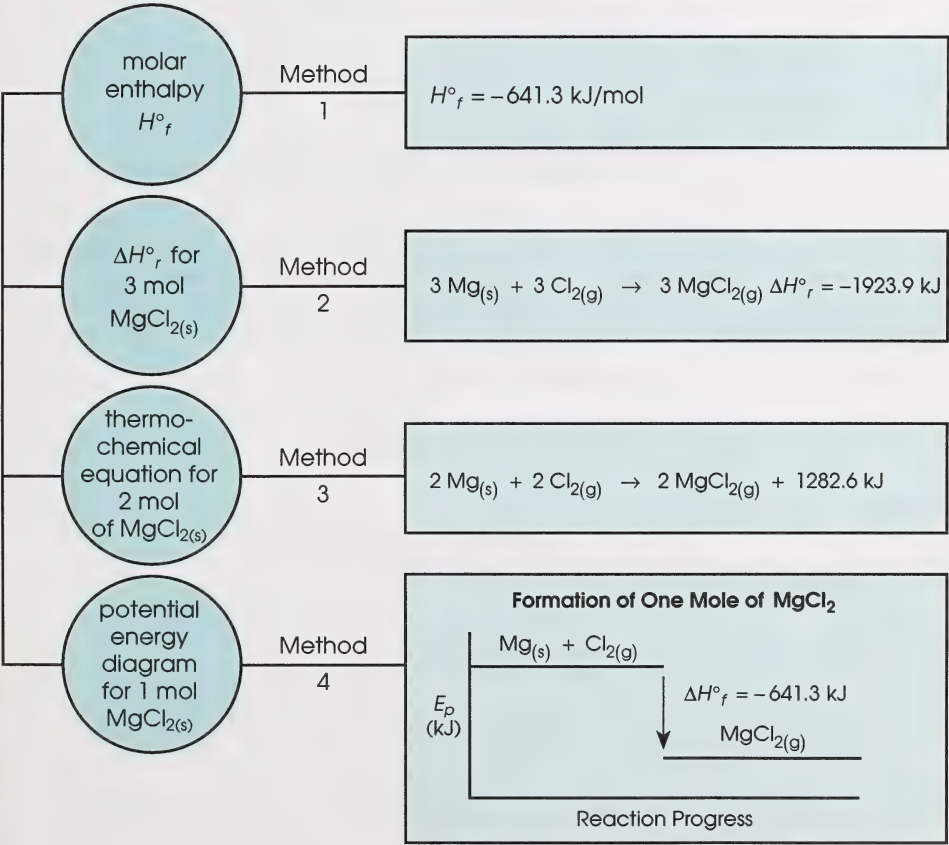
Note: The overall process of forming $\text{C}_2\text{H}_{2(g)}$ shown here involves breaking bonds in $\text{H}_{2(g)}$ **and** forming bonds in $\text{C}_2\text{H}_{2(g)}$. The **difference** in energy between the process of breaking bonds and the process of making bonds gives you the enthalpy change value of $+228.2 \text{ kJ}$.



c. $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} + 393.5 \text{ kJ}$ (Note that the combustion of carbon reaction is the same as the formation reaction of carbon dioxide.)



4.



5. The two potential energy diagrams show the reverse processes. One (photosynthesis) represents an endothermic change and the other (respiration) represents an exothermic change.
6. The enthalpy change for the cellular respiration reaction is -54 kJ , determined as follows:

$$\begin{aligned}\Delta H^\circ &= nH^\circ \\ &= 3.5 \text{ g} \times \frac{1 \text{ mol}}{180.18 \text{ g}} \times \frac{-2802.7 \text{ kJ}}{\text{mol}} \\ &= -54 \text{ kJ}\end{aligned}$$

The enthalpy change for the photosynthesis reaction is $+54 \text{ kJ}$, determined as follows:

$$\begin{aligned}\Delta H^\circ &= nH^\circ \\ &= 3.5 \text{ g} \times \frac{1 \text{ mol}}{180.18 \text{ g}} \times \frac{+2802.7 \text{ kJ}}{\text{mol}} \\ &= +54 \text{ kJ}\end{aligned}$$

7. The generalization is that the side containing the energy term has less stored energy.
- In exothermic reactions, the reactants have more stored energy than the products;
reactants $\rightarrow$ products + energy.
 - In endothermic reactions, the products have more stored energy than the reactants;
reactants + energy $\rightarrow$ products.

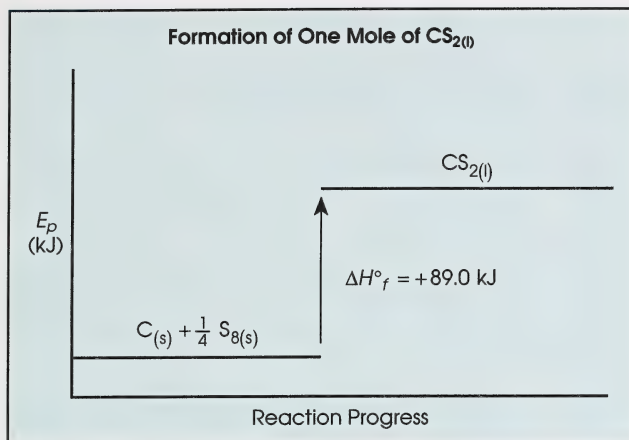
This generalization can be related to the relative stability of reactants versus products (in terms of energy only). In general, the substances with the smaller amounts of stored energy are more stable.

Section 1: Follow-up Activities

Extra Help

1. The four methods of communicating or describing enthalpy changes include
- molar enthalpies
 - enthalpy changes
 - thermochemical equations (equations containing the energy term)
 - potential energy diagrams
2. The equation is as follows: $2 \text{ Pb}_{(s)} + \text{O}_{2(g)} \rightarrow 2 \text{ PbO}_{(s)} \quad \Delta H_r = -438.0 \text{ kJ}$
3. a. The equation is as follows: $\text{C}_{(s)} + \frac{1}{4} \text{S}_{8(s)} + 89.0 \text{ kJ} \rightarrow \text{CS}_{2(l)}$

b.



4. a. endothermic b. exothermic c. endothermic d. endothermic

5. $\Delta H_r = nH_r$

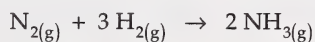
$$\begin{aligned}
 &= 1.5 \text{ mol} \times \frac{-322 \text{ kJ}}{\text{mol}} \\
 &= -483 \text{ kJ} \\
 &= -4.8 \times 10^2 \text{ kJ}
 \end{aligned}$$

The enthalpy change for 1.5 mol of $\text{N}_2\text{O}_{4(g)}$ is $-4.8 \times 10^2 \text{ kJ}$.

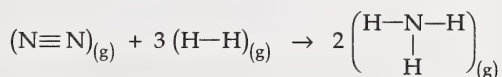
Enrichment

1. The term *bond energy* is used to describe the enthalpy change that occurs when a chemical bond is made or broken. Bond energies can be used to estimate enthalpy changes for chemical reactions.

The formation of two moles of ammonia can be represented by the following equation:



or



The enthalpy change for the reaction would involve the following changes:

- Breaking one $\text{N} \equiv \text{N}$ bond would absorb (require) $1 \times 941 \text{ kJ} = +941 \text{ kJ}$.
- Breaking three $\text{H}-\text{H}$ bonds would absorb (require) $3 \times 432 \text{ kJ} = +1296 \text{ kJ}$.
- Making six $\text{N}-\text{H}$ bonds would release $6 \times 391 \text{ kJ} = -2346 \text{ kJ}$.

Therefore, the enthalpy of reaction would be $941 \text{ kJ} + 1296 \text{ kJ} - 2346 \text{ kJ} = -109 \text{ kJ}$.

If you compare this value to two times the ΔH°_f value for $\text{NH}_{3(g)}$ (-91.8 kJ), you find that bond energies may be good as estimates, but are probably not as reliable as actual calorimetry data. (There is an 18.7% difference between the estimated bond energy value and the enthalpy table value.)

$$\begin{aligned}\% \text{ difference} &= \frac{|(-91.8 \text{ kJ}) - (-109 \text{ kJ})|}{|-91.8 \text{ kJ}|} \times 100\% \\ &= 18.7\%\end{aligned}$$

2. The advantages of using hydrogen as a fuel include the following:

- It is a completely renewable source of energy.
- Hydrogen releases considerable amounts of energy (about three times as much as methane for the same mass of each fuel) when burned.
- It is a non-polluting source of energy since the principle product is water (the word *hydrogen* is derived from a Greek term meaning "water producer").
- It can also be used as an energy carrier in that it can be easily changed to other forms of energy sources.
- It can be stored (e.g., as a liquid under pressure aboard the space shuttle) under controlled conditions.

The disadvantages of using hydrogen as a fuel include the following:

- It is difficult to store as a liquid. It has to be cooled to -252.78°C under pressure. Since it solidifies at -259.18°C , controlling the temperature is critical and can be difficult.
- There is not as yet any method available for the economical production of hydrogen. To produce hydrogen from water requires extremely large amounts of electrical energy which makes it cost-inefficient.

3. The following are some possible points that can be included in your energy-efficient ideas list:

- Increase the insulation in the walls, attic, and basement of your home.
- Place an insulation wrap around the water heater and hot water pipes.
- Use energy-efficient fluorescent light-bulbs instead of incandescent bulbs.
- Turn down the furnace thermostat one or two (or more) degrees. Dress more warmly instead.
- Turn down the water heater thermostat.
- Place caulking around windows and doors to eliminate heat leakage.
- Place insulated covers on outside wall electrical outlets and switches.
- Check the thermostat in your refrigerator so that foodstuffs are not being overcooled.

Section 2: Activity 1

1. The net change in elevation when travelling directly from Edmonton to Calgary would be

$$665 \text{ m} \xrightarrow{+383 \text{ m}} 1048 \text{ m} = +383 \text{ m}$$

(Edmonton) (Calgary)

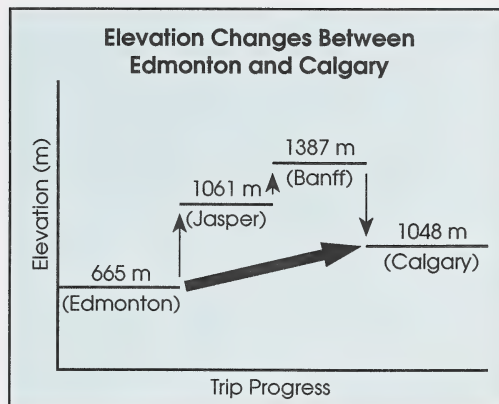
The net change in elevation when travelling from Edmonton to Jasper, then to Banff, and then on to Calgary is

$$665 \text{ m} \xrightarrow{+396 \text{ m}} 1061 \text{ m} \xrightarrow{+326 \text{ m}} 1387 \text{ m} \xrightarrow{-339 \text{ m}} 1048 \text{ m}$$

(Edmonton) (Jasper) (Banff) (Calgary)

$$= 396 \text{ m} + 326 \text{ m} - 339 \text{ m}$$

$$= +383 \text{ m}$$



Therefore, the net elevation change is the same going by either route.

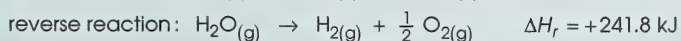
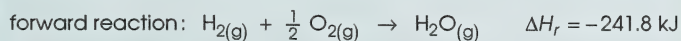
- Chemists have devised various methods to predict reaction enthalpies because it is often impossible to directly determine the reaction enthalpies of many reactions.
- The principle upon which these methods are based is that the net changes in some of the properties of a system, such as temperature and enthalpy, are independent of the pathway taken to get from the initial to final state of a reaction.
- This principle applies to enthalpy changes as follows:

If an overall reaction can be achieved by a number of different sub-reactions, but the initial reactants and final products are the same each time, the overall enthalpy change will be the same, no matter how many sub-reactions take place.

- Hess's law of heat summation states that the addition of chemical equations yields a net chemical equation whose enthalpy change is the sum of the individual positive and negative enthalpy changes.
- The two familiar rules that Hess's law uses are as follows.

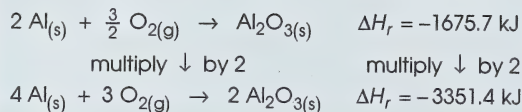
- If a chemical reaction is reversed, the sign of its ΔH_r changes.

Example



- If a chemical equation is multiplied by a factor, so is its ΔH_r .

Example



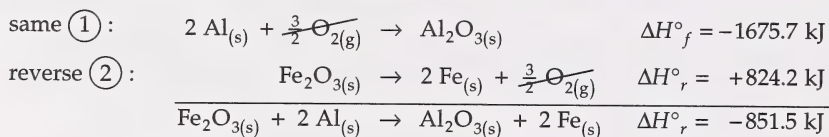
7. Do the following once you have manipulated the information equations:

- Add together all reactants and products.
- Cancel or reduce any substances that appear on both the reactant and product side of the equation.

8. Textbook question 7:

The following steps may be used:

- The first equation remains the same.
- Reverse the second equation before adding. The sign for the ΔH will become a positive value.
- Cancel like terms on opposite sides.

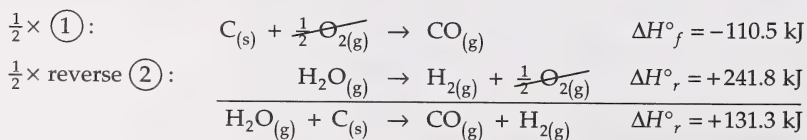


The standard enthalpy change is -851.5 kJ .

Textbook question 8:

The following method may be used:

- Divide the first equation by 2.
- Reverse the second equation and divide by 2 before adding. The sign for the ΔH will become a positive value.
- Cancel like terms on opposite sides.

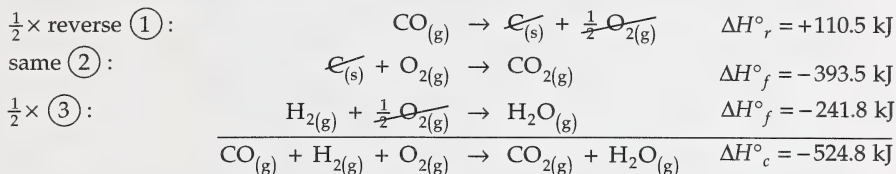


The standard enthalpy change is $+131.3 \text{ kJ}$.

Textbook question 9:

The following method may be used:

- Divide the first and third equations by two. The ΔH values will be halved as well.
- Reverse the first equation before adding. The ΔH value becomes positive.
- Cancel like terms on opposite sides of the equation.

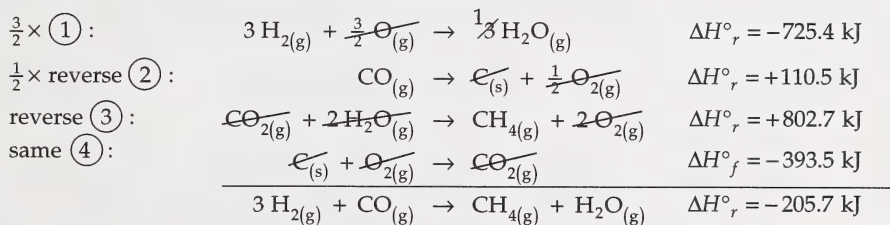


The standard enthalpy change for the combustion of coal gas is -524.8 kJ .

Textbook question 10:

The following method may be used:

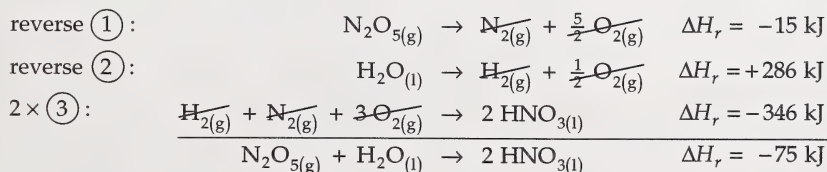
- Multiply the first equation by $\frac{3}{2}$.
- Divide the second equation by 2 and reverse the equation. The ΔH value becomes positive.
- Reverse the third equation before adding. The ΔH value becomes positive.
- Leave the fourth equation as is.



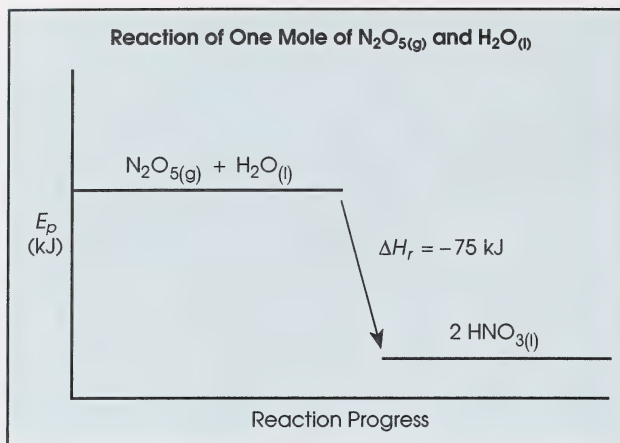
The standard enthalpy change for this methanation reaction is -205.7 kJ .

9. The following method may be used:

- Reverse the first equation. The ΔH value becomes negative.
- Reverse the second equation. The ΔH value becomes positive.
- Multiply the third equation by 2 before adding.
- Cancel like terms on opposite sides.



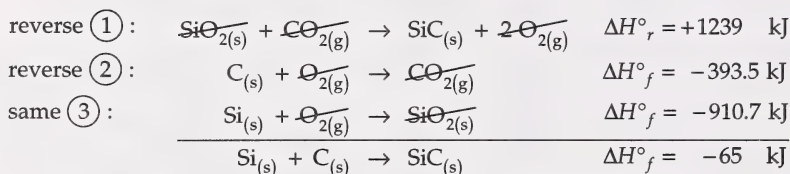
The ΔH_r is predicted to be -75 kJ .



10. This question is describing the molar enthalpy of formation reaction when you are asked to find the ΔH°_f for $\text{SiC}_{(s)}$. This required equation is as follows: $\text{Si}_{(s)} + \text{C}_{(s)} \rightarrow \text{SiC}_{(s)}$ $\Delta H^\circ_f = ?$

Therefore,

- Reverse the first equation. The ΔH value becomes positive.
- Reverse the second equation. The ΔH value becomes negative.
- Leave the third equation as is before adding.
- Cancel like terms on opposite sides.

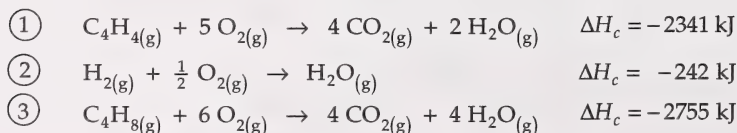


The ΔH°_f is predicted to be -65 kJ .

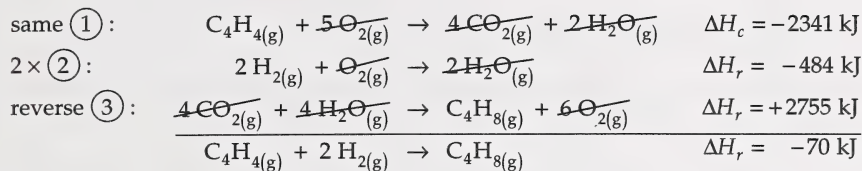
(Notice that the answer had to be rounded, because the least precise ΔH°_r value (Reaction (1)) has no decimal place.)

11. You have to write out combustion reaction equations based on the given information to answer this question. Then manipulate the equations as required.

From the given information –



The equations are manipulated as follows:

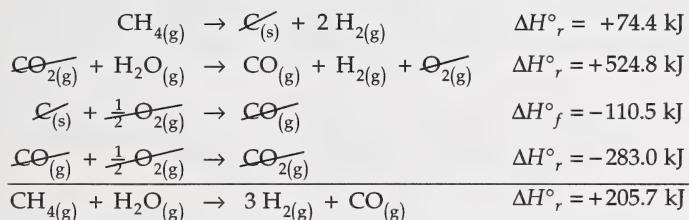


The ΔH_r is -70 kJ .

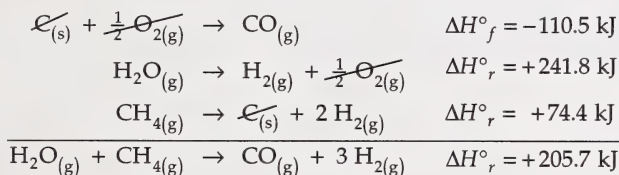
Section 2: Activity 2

- Two possible solutions are given here. However, there are other possible combinations of equations which could be used.

Combination 1



Combination 2

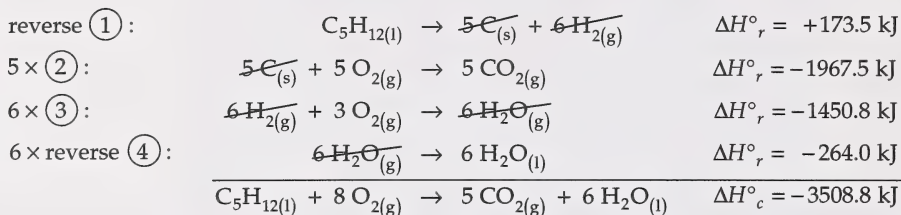


The standard enthalpy change for the production of hydrogen gas from methane and steam is $+205.7 \text{ kJ}$.

2. The equation for the combustion of one mole of pentane, where liquid water is a product, is written as follows:



According to the information equations given, the molar enthalpy of combustion of pentane is predicted as follows:



$$\begin{aligned}
 H^\circ_{\text{c}} &= \frac{\Delta H^\circ_{\text{c}}}{n} \\
 &= \frac{-3508.8 \text{ kJ}}{1 \text{ mol}} \\
 &= -3508.8 \text{ kJ/mol}
 \end{aligned}$$

The standard molar enthalpy of combustion of pentane is predicted to be -3508.8 kJ/mol .

3. According to the experimental evidence, the molar enthalpy of combustion of pentane may be calculated as follows:

$$\begin{aligned}
 \Delta H^\circ_{\text{c}} &= q \\
 (\text{pentane}) \quad (\text{calorimeter}) \\
 nH^\circ_{\text{c}} &= mc\Delta t \\
 2.15 \text{ g} \times \frac{1 \text{ mol}}{72.17 \text{ g}} \times H^\circ_{\text{c}} &= 1.24 \text{ kg} \times \frac{4.19 \text{ kJ}}{\text{kg} \cdot ^\circ\text{C}} \times (37.6 - 18.4)^\circ\text{C} \\
 H^\circ_{\text{c}} &= 3348.5 \text{ kJ/mol} \\
 &= 3.35 \text{ MJ/mol}
 \end{aligned}$$

The molar enthalpy is -3.35 MJ/mol .

4. The answers can be compared by finding the percent difference. The percent error can be calculated as follows:

$$\begin{aligned}
 \% \text{ error} &= \frac{|3.3485 \text{ MJ/mol} - 3.5088 \text{ MJ/mol}|}{|3.5088 \text{ MJ/mol}|} \times 100\% \\
 &= 4.6\%
 \end{aligned}$$

The percent error is low and suggests that the prediction is verified. Hess's law provides an acceptable value for this reaction. The error is probably due to heat losses, possible incomplete combustion, and measurement errors.

5. The procedural steps for the investigation are as follows:

- Measure 50.0 mL of 1.00 mol/L hydrochloric acid in a graduated cylinder.
- Pour the acid into a clean calorimeter and record the initial temperature of the acid solution.
- Measure 1.00 g of $\text{MgO}_{(s)}$ on a balance.
- Carefully add the $\text{MgO}_{(s)}$ to the calorimeter contents and cover immediately with a lid.
- Stir the mixture and record the maximum temperature.
- Dispose of the contents down the sink; then clean and dry the calorimeter.
- Measure and record the mass of the magnesium strip.
- Measure 50.0 mL of 1 mol/L hydrochloric acid and pour it into the calorimeter.
- Record the initial temperature of the acid.
- Add the magnesium strip to the calorimeter. Make sure all the metal is in the acid.
- Immediately cover the calorimeter with a lid.
- Stir the mixture and record the maximum temperature reached.
- Dispose of the solution down the sink.

6. A sample data table is given.

Reactant	Mass (g)	t_i of $\text{HCl}_{(aq)}$ ($^{\circ}\text{C}$)	t_f of $\text{HCl}_{(aq)}$ ($^{\circ}\text{C}$)	Volume of 1.00 mol/L $\text{HCl}_{(aq)}$ (mL)
$\text{MgO}_{(s)}$	0.93	22.8	36.1	50.0
$\text{Mg}_{(s)}$	0.15	23.2	36.9	50.0

7. Refer to the answer for Section 2: Activity 2, question 6.

8. a.
$$\Delta H_r = q$$

 (MgO reaction) (solvent water)

$$nH_r = mc\Delta t$$

$$0.93 \text{ g} \times \frac{1 \text{ mol}}{40.31 \text{ g}} \times H_r = 0.0500 \text{ kg} \times \frac{4.19 \text{ kJ}}{\text{kg} \cdot ^{\circ}\text{C}} \times (36.1 - 22.8)^{\circ}\text{C}$$

$$H_r = 120.8 \text{ kJ/mol}$$

$$= 1.2 \times 10^2 \text{ kJ/mol}$$

The molar enthalpy of reaction for magnesium oxide is $-1.2 \times 10^2 \text{ kJ/mol}$.

b.
$$\Delta H_r = q$$

 (Mg reaction) (solvent water)

$$nH_r = mc\Delta t$$

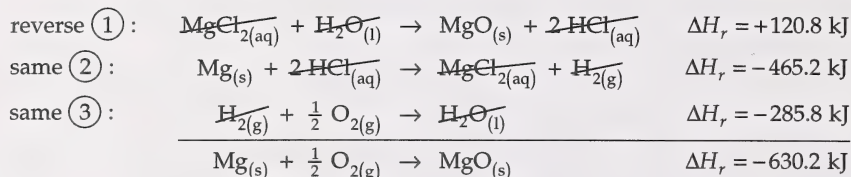
$$0.15 \text{ g} \times \frac{1 \text{ mol}}{24.31 \text{ g}} \times H_r = 0.0500 \text{ kg} \times \frac{4.19 \text{ kJ}}{\text{kg} \cdot ^{\circ}\text{C}} \times (36.9 - 23.2)^{\circ}\text{C}$$

$$H_r = 465.2 \text{ kJ/mol}$$

$$= 4.7 \times 10^2 \text{ kJ/mol}$$

The molar enthalpy of reaction for magnesium metal is $-4.7 \times 10^2 \text{ kJ/mol}$.

- c. Using Hess's law, the enthalpy change for the combustion of magnesium metal may be calculated as follows:



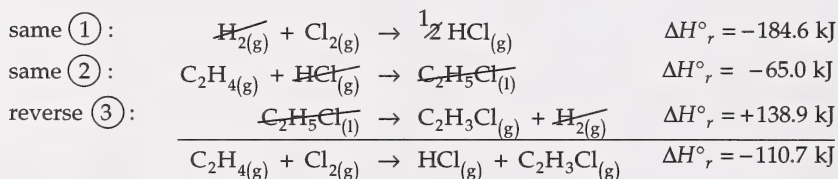
The properly rounded value for the ΔH_r of magnesium metal would be $-6.3 \times 10^2 \text{ kJ}$.

9. The evaluation of the investigation is as follows:

$$\begin{aligned}
 \% \text{ error} &= \frac{|(-630.2 \text{ kJ/mol}) - (-601.6 \text{ kJ/mol})|}{|(-601.6 \text{ kJ/mol})|} \times 100\% \\
 &= 4.8\%
 \end{aligned}$$

The percent error is calculated to be 4.8%. The prediction is verified within the limits of experimental error and the experimental design is judged to be adequate. The procedure could have been improved by including additional trials. The extra trials would likely reduce the experimental error further.

10. Textbook question 23:



The standard enthalpy change for the reaction of ethylene with chlorine is predicted to be -110.7 kJ .

Section 2: Activity 3

- The distance for the discus thrower is measured from the point of zero metres. The height for the high jumper is measured from the ground at a point of zero metres. The time for the speed skater is measured from a point of zero seconds.
- The reference energy state is a convention which defines elements as the reference point at which the potential energy is zero.
- A formation reaction can be described as a reaction which forms one mole of a substance from its elements in their natural state. The enthalpy change for a formation reaction can be described as a change in potential energy from zero (of the elements) to a final value reflected by the enthalpy change.
- Thermal stability is the tendency of a compound to resist decomposition when heated. A generalization that can be made is that the more heating required to decompose a compound, the more stable it is.

5. The standard molar enthalpy values for the substances given are as follows:

Substance	H°_f (kJ/mol)
$\text{CS}_{2(l)}$	+ 89.0
$\text{C}_2\text{H}_{2(g)}$	+ 228.2
$\text{MgCl}_{2(s)}$	- 641.3
$\text{HBr}_{(g)}$	- 36.3

To find their relative stabilities, each of these must be turned into **decomposition** values.

Substance	H°_r (kJ/mol)
$\text{CS}_{2(l)}$	- 89.0
$\text{C}_2\text{H}_{2(g)}$	- 228.2
$\text{MgCl}_{2(s)}$	+ 641.3
$\text{HBr}_{(g)}$	+ 36.3

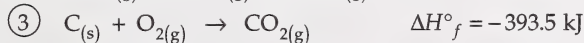
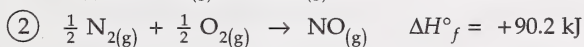
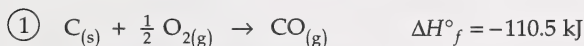
Since stability is related to how much energy it takes to decompose a substance, the substance with the largest (most positive) enthalpy of decomposition would be most stable.

Therefore, the order of the substances given from most stable to least stable (decreasing order of stability) would be $\text{MgCl}_{2(s)}$, $\text{HBr}_{(g)}$, $\text{CS}_{2(l)}$, and $\text{C}_2\text{H}_{2(g)}$.

6. The enthalpy change for the reaction $2 \text{CO}_{(g)} + 2 \text{NO}_{(g)} \rightarrow \text{N}_{2(g)} + 2 \text{CO}_{2(g)}$ can be found as follows:

Step 1

Write the formation equation and enthalpy change for each substance * given in the equation.



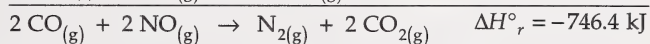
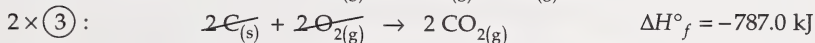
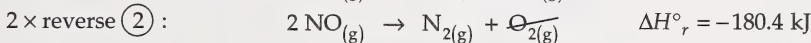
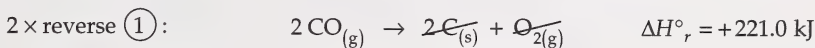
* Notice that a formation equation is not required for the $\text{N}_{2(g)}$ because the molar heat of formation for any element (which includes $\text{N}_{2(g)}$) is set at zero.

Step 2

Manipulate the formation equations and their enthalpy values so they will add up to give the desired equation.

Step 3

Add the manipulated equations and enthalpy values, and cancel common terms on opposite sides of the equations.



The enthalpy change for the reaction is -746.4 kJ.

7. The labelled equation is as follows:

$$\Delta H^\circ_r = \sum n H^\circ_{fp} - \sum n H^\circ_{fr}$$

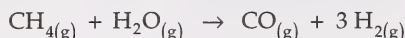
sum of number of moles from balanced equation
 ↓ ↓
 enthalpy change of the reaction standard molar enthalpy of formation for each product sum of standard molar enthalpy of formation for each reactant

8. The advantage of this method is that the enthalpies of formation given for a few chemicals allow you to calculate enthalpy changes for a large number and variety of chemical reactions.

9. **Textbook question 11:**

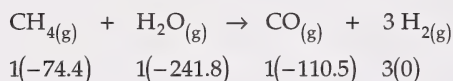
Note: To minimize error, you will find it easiest if you develop a consistent method of answering questions such as these. One possible method will be shown here as these questions are answered.

- a. **Step 1** Write out the desired equation.



Step 2

Find the standard molar enthalpy of formation values for each substance (from the table on page 551 of *Nelson Chemistry*) and write them under each substance in the equation. Remember, the molar enthalpy of formation value for any element is zero.

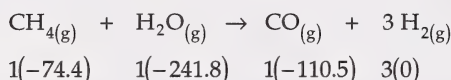


↑

It is a good idea to include the coefficient amounts so you don't forget them.

Step 3

Set up the products minus reactants equation and solve for the enthalpy change of the reaction.



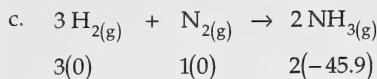
$$\begin{aligned} \Delta H^\circ_r &= \sum nH^\circ_{fp} - \sum nH^\circ_{fr} \\ &= \left(1 \text{ mol} \times \frac{-110.5 \text{ kJ}}{\text{mol}} + 3 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) - \left(1 \text{ mol} \times \frac{-74.4 \text{ kJ}}{\text{mol}} + 1 \text{ mol} \times \frac{-241.8 \text{ kJ}}{\text{mol}} \right) \\ &= +205.7 \text{ kJ} \end{aligned}$$

The enthalpy change for this reaction is +205.7 kJ.

- b. $\text{CO}_{(g)} + \text{H}_2\text{O}_{(g)} \rightarrow \text{CO}_{2(g)} + \text{H}_{2(g)}$
 $1(-110.5) \quad 1(-241.8) \quad 1(-393.5) \quad 1(0)$

$$\begin{aligned} \Delta H^\circ_r &= \sum nH^\circ_{fp} - \sum nH^\circ_{fr} \\ &= \left(1 \text{ mol} \times \frac{-393.5 \text{ kJ}}{\text{mol}} + 1 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) - \left(1 \text{ mol} \times \frac{-110.5 \text{ kJ}}{\text{mol}} + 1 \text{ mol} \times \frac{-241.8 \text{ kJ}}{\text{mol}} \right) \\ &= -41.2 \text{ kJ} \end{aligned}$$

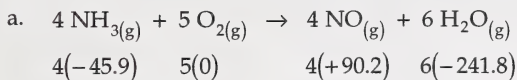
The enthalpy change for the reaction is -41.2 kJ.



$$\begin{aligned} \Delta H^\circ_r &= \sum nH^\circ_{fp} - \sum nH^\circ_{fr} \\ &= \left(2 \text{ mol} \times \frac{-45.9 \text{ kJ}}{\text{mol}} \right) - \left(3 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} + 1 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) \\ &= -91.8 \text{ kJ} \end{aligned}$$

The enthalpy change for the formation reaction is -91.8 kJ .

Textbook question 12:

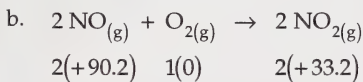


$$\begin{aligned} \Delta H^\circ_r &= \sum nH^\circ_{fp} - \sum nH^\circ_{fr} \\ &= \left(4 \text{ mol} \times \frac{+90.2 \text{ kJ}}{\text{mol}} + 6 \text{ mol} \times \frac{-241.8 \text{ kJ}}{\text{mol}} \right) - \left(4 \text{ mol} \times \frac{-45.9 \text{ kJ}}{\text{mol}} + 5 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) \\ &= -906.4 \text{ kJ} \end{aligned}$$

The standard enthalpy change for the reaction is -906.4 kJ .

$$\begin{aligned} H^\circ_r &= \frac{\Delta H^\circ_r}{n} \\ &= \frac{-906.4 \text{ kJ}}{4 \text{ mol}} \\ &= -226.6 \text{ kJ/mol} \end{aligned}$$

The standard molar enthalpy of reaction for $\text{NH}_{3(\text{g})}$ is -226.6 kJ/mol .

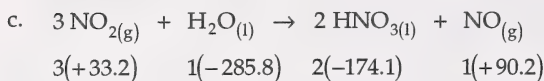


$$\begin{aligned} \Delta H^\circ_r &= \sum nH^\circ_{fp} - \sum nH^\circ_{fr} \\ &= \left(2 \text{ mol} \times \frac{+33.2 \text{ kJ}}{\text{mol}} \right) - \left(2 \text{ mol} \times \frac{+90.2 \text{ kJ}}{\text{mol}} + 1 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) \\ &= -114.0 \text{ kJ} \end{aligned}$$

The standard enthalpy change for the reaction is -114.0 kJ .

$$\begin{aligned}
 H_r^\circ &= \frac{\Delta H_r^\circ}{n} \\
 &= \frac{-114.0 \text{ kJ}}{2 \text{ mol}} \\
 &= -57.0 \text{ kJ/mol}
 \end{aligned}$$

The standard molar enthalpy of reaction for $\text{NO}_{(g)}$ is -57.0 kJ/mol .



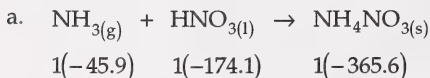
$$\begin{aligned}
 \Delta H_r^\circ &= \left(2 \text{ mol} \times \frac{-174.1 \text{ kJ}}{\text{mol}} + 1 \text{ mol} \times \frac{+90.2 \text{ kJ}}{\text{mol}} \right) - \left(3 \text{ mol} \times \frac{+33.2 \text{ kJ}}{\text{mol}} + 1 \text{ mol} \times \frac{-285.8 \text{ kJ}}{\text{mol}} \right) \\
 &= -71.8 \text{ kJ}
 \end{aligned}$$

The standard enthalpy change for the reaction is -71.8 kJ .

$$\begin{aligned}
 H_r^\circ &= \frac{\Delta H_r^\circ}{n} \\
 &= \frac{-71.8 \text{ kJ}}{3 \text{ mol}} \\
 &= -23.9 \text{ kJ/mol}
 \end{aligned}$$

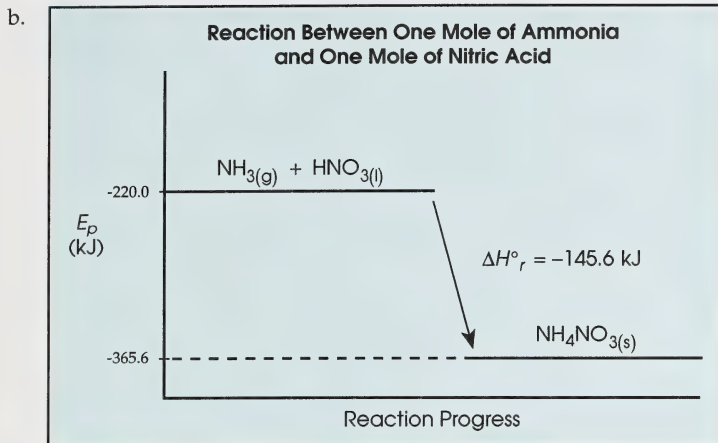
The standard molar enthalpy of reaction for $\text{NO}_{2(g)}$ is -23.9 kJ/mol .

Textbook question 13:



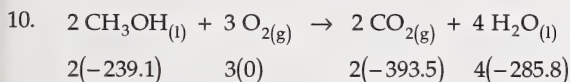
$$\begin{aligned}
 \Delta H_r^\circ &= \sum nH_{fp}^\circ - \sum nH_{fr}^\circ \\
 &= \left(1 \text{ mol} \times \frac{-365.6 \text{ kJ}}{\text{mol}} \right) - \left(1 \text{ mol} \times \frac{-45.9 \text{ kJ}}{\text{mol}} + 1 \text{ mol} \times \frac{-174.1 \text{ kJ}}{\text{mol}} \right) \\
 &= -145.6 \text{ kJ}
 \end{aligned}$$

The standard enthalpy change for the reaction is -145.6 kJ .

**Textbook question 14:**

You can select any of the five perspectives given in the margin notes on page 538 of *Nelson Chemistry*. Some of the perspectives may include the following:

- Economic perspective – The technological design must be cost-efficient.
- Ecological perspective – The benefits from the proper use of fertilizers usually outweighs the problems of runoff from fields affecting weed growth in lakes and rivers.
- Scientific perspective – Chemical reactions form the basis for this industry, and yield depends upon scientific laws of stoichiometry.
- Social perspective – Growth of communities depends upon fertilizer production because fertilizers enhance crop yield; higher yields sustain bigger populations.
- Technological perspective – Manufacturers use the most reliable and cost-efficient method of production.



$$\begin{aligned} \Delta H^\circ_c &= \sum nH^\circ_{fp} - \sum nH^\circ_{fr} \\ &= \left(2 \text{ mol} \times \frac{-393.5 \text{ kJ}}{\text{mol}} + 4 \text{ mol} \times \frac{-285.8 \text{ kJ}}{\text{mol}} \right) - \left(2 \text{ mol} \times \frac{-239.1 \text{ kJ}}{\text{mol}} + 3 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) \\ &= -1452.0 \text{ kJ} \end{aligned}$$

$$\begin{aligned} H^\circ_c &= \frac{-1452.0 \text{ kJ}}{2 \text{ mol}} \\ &= -726.0 \text{ kJ/mol} \end{aligned}$$

The predicted molar enthalpy of combustion for methanol is -726.0 kJ/mol .

$$\begin{aligned}
 11. \quad \Delta H_c &= q \\
 \left(\begin{array}{c} \text{methanol} \\ \text{combustion} \end{array} \right) & \left(\begin{array}{c} \text{calorimeter} \\ \text{water} \end{array} \right) \\
 nH_c &= C\Delta t \\
 4.38 \text{ g} \times \frac{1 \text{ mol}}{32.05 \text{ g}} \times H_c &= \frac{10.9 \text{ kJ}}{^\circ\text{C}} \times (27.9 - 20.4)^\circ\text{C} \\
 H_c &= 598.19 \text{ kJ/mol} \\
 &= 598 \text{ kJ/mol}
 \end{aligned}$$

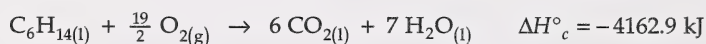
The experimental molar enthalpy of combustion for methanol is -598 kJ/mol .

12. The predicted and experimental values can be compared by calculating the percent error.

$$\begin{aligned}
 \% \text{ error} &= \frac{|(-598.19 \text{ kJ}) - (-726.0 \text{ kJ})|}{|-726.0 \text{ kJ}|} \times 100\% \\
 &= 17.6\%
 \end{aligned}$$

Since the percent error is large, the prediction is not verified. This may be due to the assumptions involved when using a calorimeter. The error may also be due to having only one set of data. The experiment should be repeated since the values reported for the evidence use only one trial. Therefore, a judgement of the acceptability of the molar enthalpies of formation method cannot be made.

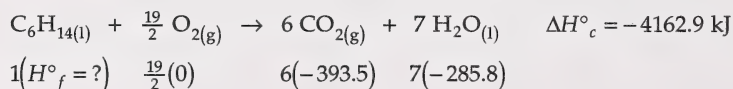
13. **Step 1** Write out the chemical equation for the combustion of hexane and attach the given H_c° value.



The equation is balanced for one mole of hexane so the given H_c° value fits in directly.

Instead of finding the enthalpy of reaction, given all the H_f° values, you have to solve for an unknown H_f° value given the enthalpy of reaction. Therefore, you can use the same method, $\Delta H_r^\circ = \sum nH_{fp}^\circ - \sum nH_{fr}^\circ$, but you are solving for a different variable in the equation.

- Step 2** Find the H_f° values from the enthalpy table for all the known substances.



Step 3

Set up the *products minus reactants* equation and solve.

$$\begin{aligned}\Delta H_c^\circ &= \sum nH_{fp}^\circ - \sum nH_{fr}^\circ \\ -4162.9 \text{ kJ} &= \left(6 \text{ mol} \times \frac{-393.5 \text{ kJ}}{\text{mol}} + 7 \text{ mol} \times \frac{-285.8 \text{ kJ}}{\text{mol}} \right) - \left(1 \text{ mol} \times H_f^\circ + \frac{19}{2} \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) \\ -4162.9 \text{ kJ} &= (-4361.6 \text{ kJ}) - (1 \text{ mol} \times H_f^\circ) \\ 198.7 \text{ kJ} &= -1 \text{ mol} \times H_f^\circ \\ \frac{198.7 \text{ kJ}}{-1 \text{ mol}} &= H_f^\circ \\ H_f^\circ &= -198.7 \text{ kJ/mol}\end{aligned}$$

Caution! Watch out for those negative signs!

The standard molar enthalpy of formation for hexane is -198.7 kJ/mol .

You can prove to yourself that this method works by checking your calculated value against the H_f° value on the standard molar enthalpy table – they are the same.

14. The following steps can be followed to calculate the molar enthalpy of formation for cyclohexane.

Step 1

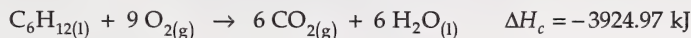
Calculate the molar enthalpy of combustion for cyclohexane using the calorimetry data given.

$$\begin{aligned}\Delta H_c &= q \\ \left(\begin{array}{c} \text{cyclohexane} \\ \text{combustion} \end{array} \right) & \left(\begin{array}{c} \text{calorimeter} \\ \text{water} \end{array} \right) \\ nH_c &= C\Delta t \\ 1.43 \text{ g} \times \frac{1 \text{ mol}}{84.18 \text{ g}} \times H_c &= \frac{10.5 \text{ kJ}}{^\circ\text{C}} \times (26.67 - 20.32)^\circ\text{C} \\ H_c &= 3924.97 \text{ kJ/mol} \\ &= 3.92 \times 10^3 \text{ kJ/mol (3.92 MJ/mol)}\end{aligned}$$

The molar enthalpy of combustion for cyclohexane is $-3.92 \times 10^3 \text{ kJ/mol}$ (-3.92 MJ/mol).

Step 2

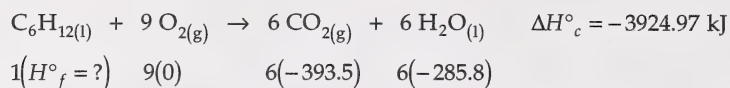
Write the combustion equation for one mole of cyclohexane.



↑
Extra digits are kept for the next calculation.

Step 3

Find the H°_f values for the substances other than cyclohexane and solve for the H°_f of cyclohexane.



$$\begin{aligned} \Delta H^\circ_c &= \sum n\Delta H^\circ_{fp} - \sum n\Delta H^\circ_{fr} \\ -3924.97 \text{ kJ} &= \left(6 \text{ mol} \times \frac{-393.5 \text{ kJ}}{\text{mol}} + 6 \text{ mol} \times \frac{-285.8 \text{ kJ}}{\text{mol}} \right) - \left(1 \text{ mol} \times H^\circ_f + 9 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) \\ -3924.97 \text{ kJ} &= (-4075.8 \text{ kJ}) - 1 \text{ mol} \times H^\circ_f \\ 150.8 \text{ kJ} &= -1 \text{ mol} \times H^\circ_f \\ H^\circ_f &= -150.8 \text{ kJ/mol} \\ &= -151 \text{ kJ/mol} \end{aligned}$$

The standard molar enthalpy of formation for cyclohexane is -151 kJ/mol .

Section 2: Follow-up Activities**Extra Help**

1.

Step 1 Write the required balanced chemical equation.



Step 2 Manipulate the given information equations.



Step 3 Add the reactants and products and cancel common terms on opposite sides.



Step 4 Add the step enthalpies to get the overall enthalpy.



Step 5 Find the molar enthalpy, if required.

**Using
Hess's Law**

2. a. The relationship is $\Delta H^\circ_1 = \Delta H^\circ_2 + \Delta H^\circ_3$.
- b. The value for $\Delta H^\circ_2 = \Delta H^\circ_1 - \Delta H^\circ_3$
- $$= -393.5 \text{ kJ} - (-283.0 \text{ kJ})$$
- $$= -110.5 \text{ kJ}$$

The value for ΔH°_2 is -110.5 kJ .

3. $\frac{1}{2} \times \text{reverse } (1)$: $\text{Cr}_2\text{O}_{3(s)} \rightarrow 2 \text{Cr}_{(s)} + \cancel{\frac{3}{2} \text{O}_{2(g)}} \quad \Delta H^\circ_r = +1139.7 \text{ kJ}$
- $3 \times (2)$: $3 \text{C}_{(s)} + \cancel{\frac{3}{2} \text{O}_{2(g)}} \rightarrow 3 \text{CO}_{(g)} \quad \Delta H^\circ_r = -331.5 \text{ kJ}$
-
- $\text{Cr}_2\text{O}_{3(s)} + 3 \text{C}_{(s)} \rightarrow 2 \text{Cr}_{(s)} + 3 \text{CO}_{(g)} \quad \Delta H^\circ_r = +808.2 \text{ kJ}$

The enthalpy change for the reaction is $+808.2 \text{ kJ}$.

4. Methane ($\text{CH}_{4(g)}$) should be more stable than the reactants because methane has less stored (potential) energy.
5. $\text{C}_6\text{H}_{12}\text{O}_{6(s)} + 6 \text{O}_{2(g)} \rightarrow 6 \text{CO}_{2(g)} + 6 \text{H}_2\text{O}_{(g)}$
- $1(-1273.1) \quad 6(0) \quad 6(-393.5) \quad 6(-241.8)$

$$\Delta H^\circ_r = \sum nH^\circ_{fp} - \sum nH^\circ_{fr}$$

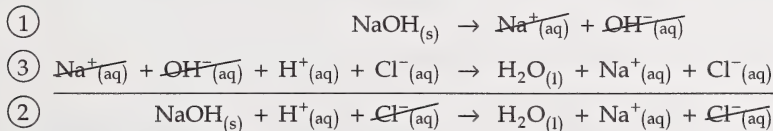
$$= \left(6 \text{ mol} \times \frac{-393.5 \text{ kJ}}{\text{mol}} + 6 \text{ mol} \times \frac{-241.8 \text{ kJ}}{\text{mol}} \right) - \left(1 \text{ mol} \times \frac{-1273.1 \text{ kJ}}{\text{mol}} + 6 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right)$$

$$= -2538.7 \text{ kJ}$$

The enthalpy change for the combustion of glucose is -2538.7 kJ .

Enrichment

1. a. The sum of equations for Reactions (1) and (3) equals the equation for Reaction (2).



Note: The ion $\text{Cl}^-_{(aq)}$ is shown cancelled in Reaction (2) just to indicate what would be the net ionic equation.

- b. The design for the investigation is as follows:

Each of the reactions (1), (2), and (3) is performed separately in a simple polystyrene calorimeter and temperature measurements are taken.

- c. One possible procedure for this investigation is as follows:

Reaction (1)

- Add 100 mL of distilled water to a clean calorimeter.
- Measure and record the initial temperature of the water.
- Measure 2.00 g of $\text{NaOH}_{(s)}$ on a balance.
- Add the 2.00 g of $\text{NaOH}_{(s)}$ to the water in the calorimeter and cover immediately with the lid.
- Carefully stir the mixture with the thermometer and record the maximum temperature of the mixture.
- Dispose of the contents following safety procedures; then clean and dry the calorimeter.
- Repeat the procedure if time permits.

Reaction (2)

- Add 100 mL of 0.50 mol/L $\text{HCl}_{(aq)}$ to a clean calorimeter.
- Measure and record the initial temperature of the acid solution.
- Measure 2.00 g of $\text{NaOH}_{(s)}$ on a balance.
- Add the 2.00 g of $\text{NaOH}_{(s)}$ to the acid in the calorimeter and cover immediately with the lid.
- Carefully stir the mixture with the thermometer and record the maximum temperature of the mixture.
- Dispose of the contents following safety procedures; then clean and dry the calorimeter.
- Repeat the procedure if time permits.

Reaction (3)

- Add 50.0 mL of 1.00 mol/L $\text{HCl}_{(aq)}$ to a clean beaker.
- Add 50.0 mL of 1.00 mol/L $\text{NaOH}_{(aq)}$ to a different clean beaker.
- Allow both solutions to come to the same (room) temperature.
- Record the initial temperature of each solution.
- Add the $\text{NaOH}_{(aq)}$ solution to a clean calorimeter containing a thermometer.
- Add the $\text{HCl}_{(aq)}$ solution to the same calorimeter and cover immediately with the lid.
- Measure and record the maximum temperature of the mixture.
- Dispose of the contents safely.
- Repeat the procedure if time permits.

2. The Born-Haber cycle is an application of Hess's law and is usually applied to the formation of ionic solids from their elements. It involves a five-step process which can be applied to many different ionic compounds. The example process shown here uses lithium fluoride.

BORN-HABER CYCLE		
Step	Process	Energy Change
1	Sublimation: $\text{Li}_{(s)} \rightarrow \text{Li}_{(g)}$	$\Delta H_r = +161 \text{ kJ} \leftarrow$ sublimation energy
2	Ionization: $\text{Li}_{(g)} \rightarrow \text{Li}^+_{(g)} + \text{e}^-$	$\Delta H_r = +520 \text{ kJ} \leftarrow$ ionization energy
3	Dissociation: $\frac{1}{2} \text{F}_{2(g)} \rightarrow \text{F}_{(g)}$	$\Delta H_r = +77 \text{ kJ} \leftarrow$ dissociation energy
4	Formation: $\text{F}_{(g)} + \text{e}^- \rightarrow \text{F}^-_{(g)}$	$\Delta H_r = -328 \text{ kJ} \leftarrow$ electron affinity
5	Formation: $\text{Li}^+_{(g)} + \text{F}^-_{(g)} \rightarrow \text{LiF}_{(s)}$	$\Delta H_r = -1047 \text{ kJ} \leftarrow$ lattice energy
Overall:	$\text{Li}_{(s)} + \frac{1}{2} \text{F}_{2(g)} \rightarrow \text{LiF}_{(s)}$	$\Delta H_r = -617 \text{ kJ}$

Any one step can also be found using the other four steps, the overall reaction, and Hess's law.

3. The Haber-Bosch process was developed to produce ammonia for ammonia-based fertilizers according to the following overall equation:



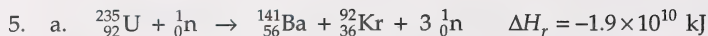
The process, though, involves a number of sub-reaction steps which bring the nitrogen and hydrogen gases to the point where they can combine to form the ammonia. To maximize the yield of ammonia, engineers and chemists have designed an ammonia synthesizer which adjusts factors such as temperature and pressure while running through the sub-steps.

Section 3: Activity 1

1. An enthalpy change in a nuclear reaction is a result of breaking and making bonds between the particles (protons and neutrons) in the nucleus of an atom.
2. The type of nuclear reaction that occurs in the sun is called a fusion reaction. In fusion reactions, smaller atoms are fused together to make larger atoms, releasing an enormous amount of energy.
3. As outlined on page 59 of your textbook, *Nelson Chemistry*, the symbols are described as follows:

mass number $\rightarrow {}^2\text{H}$ mass number – the number of protons and neutrons in the nucleus of an atom
 atomic number $\rightarrow {}^1\text{H}$ atomic number – the number of protons in the nucleus of an atom

4. Solar energy provides energy to plants to convert carbon dioxide and water into oxygen and glucose. Fossil fuels are thought to be the remains of plants and animals. Because the plants and animals had originally depended on solar energy, the solar energy is considered trapped in the fossil fuels and is reused by society today.

b. **Step 1**

Calculate the molar enthalpy of reaction for ${}^{235}_{92}\text{U}$.

$$\begin{aligned} H_r &= \frac{\Delta H_r}{n} \\ &= \frac{-1.9 \times 10^{10} \text{ kJ}}{1 \text{ mol}} \\ &= -1.9 \times 10^{10} \text{ kJ/mol} \end{aligned}$$

Step 2

Calculate the enthalpy change for 25.0 g of uranium-235 reacting.

$$\begin{aligned} \Delta H_r &= \frac{-1.9 \times 10^{10} \text{ kJ}}{1 \text{ mol}} \times \frac{1 \text{ mol}}{235 \text{ g}} \times 25.0 \text{ g} \\ &= -2.0 \times 10^9 \text{ kJ} \end{aligned}$$

The enthalpy change for the reaction is $-2.0 \times 10^9 \text{ kJ}$.

6. The nuclear change equation will have element symbols illustrating the mass number and atomic number for each element and particle involved.
7. A typical example could be as follows. The given example shows a rate of radiation below the average (260 millirems) and below the established safe level (500 millirems).

Compare Your Annual Radiation Dose (Calculated as Dose to Bone Marrow)		
	Source of Exposure	Your Annual Dose (Millirems)
Where you live	Natural cosmic radiation at sea level (Add 3 for every 150 m above sea level.)	28 15
	Ground Radon gas	26 80
	House construction (based on 18 h/day in house) (masonry = 7; wood = 0)	0
What you eat, drink, and breathe	Naturally occurring radio-nuclides in food and water Fallout from previous nuclear weapons tests	24 4
How you live	10 000 km jet flight (cosmic radiation during flight = 4; number of flights per year $\times$ 4)	4
	Chest X-ray (number per year $\times$ 10)	10
	Upper gastrointestinal X-ray (number per year $\times$ 535)	0
	Dental X-ray (number per year $\times$ 10)	30
Living near CANDU nuclear station	At reactor site boundary = 2 1.6 km from boundary = 0.7 8 km from boundary = 0.1	0
	TOTAL	221
Compare your average with the North American average of 260 millirems or 2.6 msv.		

¹ Reprinted with permission from the Canadian Nuclear Association, *Nuclear Facts*, Number 13, 3-1989.

8. Foods are irradiated with cobalt-60 to destroy the microorganisms that normally cause spoilage; cobalt-60 makes food safe to eat, and prolongs the shelf-life of foods by slowing the ripening process.
9. Cobalt-60 can also be used to sterilize medical products. Irradiation permits the sterilization of heat-sensitive materials such as plastic and is often the only method of sterilizing some pharmaceutical products.

10.

Type of Change	Type of Energy	Types of Bonds Involved
Phase	potential	breaking and making intermolecular bonds
Chemical	potential	breaking and making intramolecular bonds
Nuclear	potential	breaking and making bonds between particles in the nucleus

11. The relative energy change magnitudes are as follows:

- phase changes: 10^1 kJ/mol – 10^2 kJ/mol
- chemical changes: 10^2 kJ/mol – 10^3 kJ/mol
- nuclear changes: $\geq 10^9$ kJ/mol

12. The statements are matched to the equations as follows:

- a. III b. I c. II d. IV

13. Alternative d will release the most energy because it involves a nuclear change.

14.

Step 1

Calculate the molar enthalpy.

$$\begin{aligned}
 H_r &= \frac{\Delta H_r}{n} \\
 &= \frac{-1.70 \times 10^9 \text{ kJ}}{1 \text{ mol}} \\
 &= -1.70 \times 10^9 \text{ kJ/mol}
 \end{aligned}$$

The molar enthalpy of reaction for ${}^3_1\text{H}$ is -1.70×10^9 kJ/mol.

Step 2

Calculate the mass reacted.

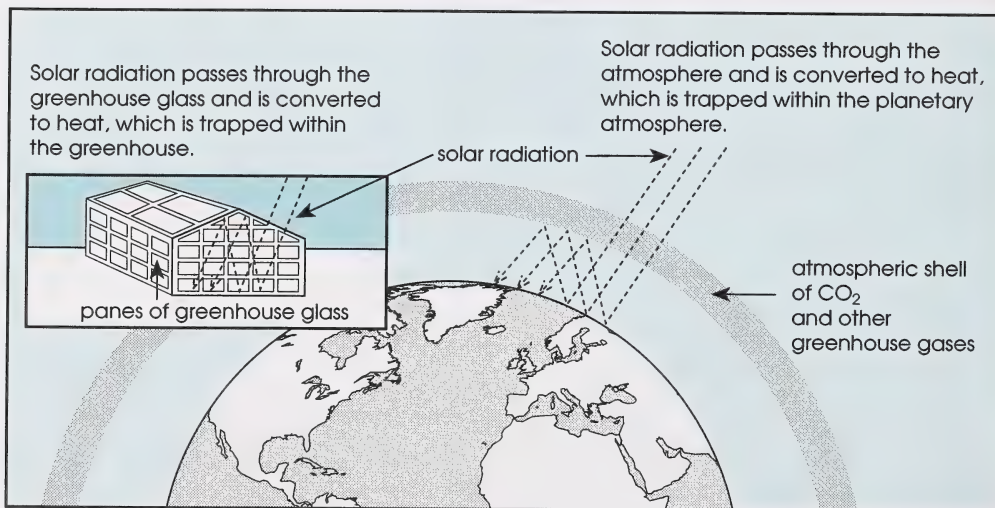
$$\begin{aligned}
 m &= 6.50 \times 10^{10} \text{ kJ} \times \frac{1 \text{ mol}}{1.70 \times 10^9 \text{ kJ}} \times \frac{3.00 \text{ g}}{1 \text{ mol}} \\
 &= 115 \text{ g}
 \end{aligned}$$

The mass of ${}^3_1\text{H}$ reacted is 115 g.

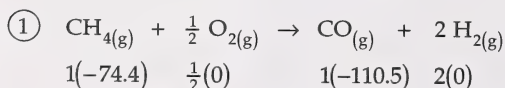
Notice that it only takes 115 g of tritium (${}^3_1\text{H}$) reacting to release 65 billion kilojoules of energy!

Section 3: Activity 2

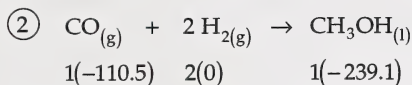
- The three major demands for energy are transportation, industry, and heating buildings.
- Some possible problems with burning fossil fuels are as follows:
 - Some oil fuels contain sulphur compounds. When these burn they produce sulphur dioxide and sulphur trioxide. These oxides dissolve in water in the atmosphere and come down as acid rain.
 - Coal has to be made smoke free before it can be used. This is done by heating coal in the absence of air. This produces coal tar, which is a health hazard.
 - Carbon dioxide, the main product of fossil fuel combustion, is causing global warming.
 - Raw materials for the petrochemical industry are becoming short in supply.
 - Costs of non-renewable resources will soon become prohibitive.
- Carbon dioxide emissions have increased due to increased demands for energy and therefore increased burning of fossil fuels. Solar energy penetrates the atmosphere to reach the surface of the Earth and in the process creates heat in the lower atmosphere near the Earth's surface. The carbon dioxide and other gases trap this heat and do not allow it to be circulated into the upper atmosphere. This has resulted in global warming. The diagram that follows shows how this happens.



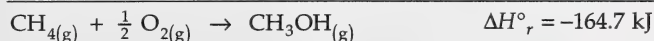
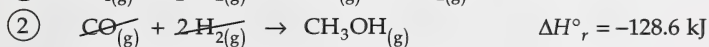
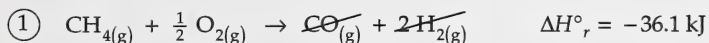
- Biomass is plant material present in algae, waterplants, grass, trees, etc.
- a. The two equations are as follows:



$$\begin{aligned}
 \Delta H^\circ_r &= \sum nH^\circ_{fp} - \sum nH^\circ_{fr} \\
 &= \left(1 \text{ mol} \times \frac{-110.5 \text{ kJ}}{\text{mol}} + 2 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) - \left(1 \text{ mol} \times \frac{-74.4 \text{ kJ}}{\text{mol}} + \frac{1}{2} \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) \\
 &= -36.1 \text{ kJ}
 \end{aligned}$$

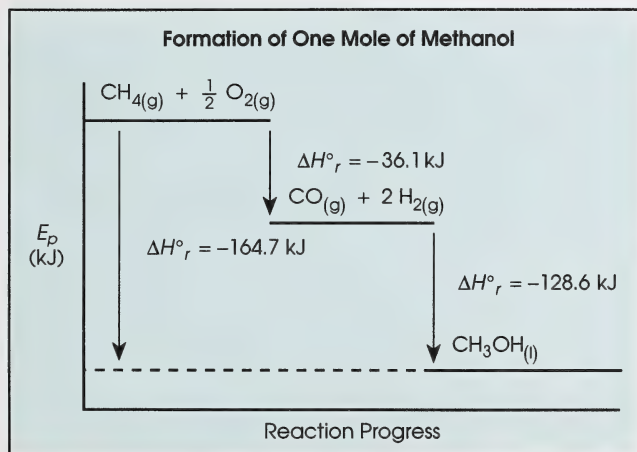


$$\begin{aligned}
 \Delta H^\circ_r &= \sum nH^\circ_{fp} - \sum nH^\circ_{fr} \\
 &= \left(1 \text{ mol} \times \frac{-239.1 \text{ kJ}}{\text{mol}} \right) - \left(1 \text{ mol} \times \frac{-110.5 \text{ kJ}}{\text{mol}} + 2 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) \\
 &= -128.6 \text{ kJ}
 \end{aligned}$$

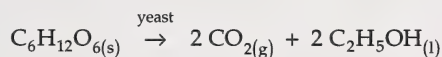


The enthalpy change for the net overall reaction is -164.7 kJ .

b.



6. Brazil uses ethanol extensively as a fuel.
7. Ethanol is produced from the fermentation of sugar by yeast.



8. a. The distillation method of producing ethanol is not very efficient because for every 100 kJ of energy supplied by ethanol, it takes 85 kJ of energy to produce it. That only leaves 15 kJ of net energy gain.
- b. A concentrated solution of potassium carbonate mixed with an ethanol solution causes the ethanol to separate and float to the top of the solution. The ethanol can then be separated out.
9. Cellulose has a rubbery lignin coat which cannot be digested by yeast. Also, the sugar molecules in the cellulose are bonded in such a way that the yeast cannot break down the sugar chains.
10. Possible questions to be asked are as follows:
 - Should standing forests be used to produce the ethanol?
 - Will tree farming deplete or improve the soil?
 - Is the expense of producing ethanol worth the effort?
11. At present, it is still easier and cheaper to pump oil out of the ground and to process it as a fuel.
12. The emissions will have minimal environmental impact because the products of hydrogen combustion are water and energy.
13. The hydrogen is stored in a tank as a metal hydride.
14. If you agree that ethanol is a good alternative source of fuel, you may defend your decision as follows.
 - Scientific perspective – The process of fermentation is well-established and can be controlled.
 - Technological perspective – The technology for either distillation or separation of ethanol exists already.
 - Ecological perspective – The production process could make use of otherwise undesirable stands of trees and utilize much waste material. Also, ethanol produces less $\text{CO}_{2(g)}$ than gasoline per kilojoule of energy produced.
 - Economic perspective – The public will be willing to pay a little more for a technology that is renewable.

If you disagree that ethanol is a good alternative fuel source, you may defend your answer as follows.

- Scientific perspective – The combustion of ethanol is not as energy-productive as other fuels like gasoline.
- Technological perspective – The technology of the distillation processing is not energy-efficient.
- Ecological perspective – The production and combustion of ethanol still produces carbon dioxide and water vapour. The carbon dioxide contributes to global warming.
- Economic perspective – The distillation process is not cost-efficient and the cost per 100 km of travel using ethanol would be prohibitive.

15. Textbook question 19:

$$\begin{aligned}
 H_c^\circ &= \frac{\Delta H_c^\circ}{n} \\
 &= \frac{-44.0 \text{ MJ}}{2 \text{ mol}} \\
 &= -22.0 \text{ MJ/mol}
 \end{aligned}$$

$$\begin{aligned}
 \Delta H_c^\circ &= 1.00 \times 10^5 \text{ g} \times \frac{1 \text{ mol}}{656.68 \text{ g}} \times \frac{22.0 \text{ MJ}}{1 \text{ mol}} \\
 &= 3.35 \times 10^3 \text{ MJ} \\
 &= 3.35 \text{ GJ}
 \end{aligned}$$

The quantity of energy available is 3.35 GJ.

Textbook question 20:

Some alternative energy sources are solar energy, nuclear energy, hydro energy, and wind energy.

Hydro energy is used as an example here.

Advantages	Disadvantages
- Fossil fuels are conserved. - The process of acquiring the energy is environmentally safe with little pollution. - The technology needed for development already exists.	- It causes ecological imbalance due to flooding of land and dam building. - It is not easy to build dams in all areas.

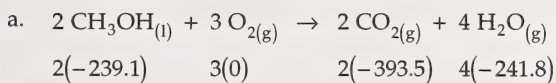
Textbook question 21:

$$\begin{aligned}
 H_c^\circ &= \frac{\Delta H_c^\circ}{n} \\
 &= \frac{-10\,148.2 \text{ kJ}}{2 \text{ mol}} \\
 &= -5074.1 \text{ kJ/mol}
 \end{aligned}$$

$$\begin{aligned}
 \Delta H_c^\circ &= 1000 \text{ g} \times \frac{1 \text{ mol}}{114.26 \text{ g}} \times \frac{5074.1 \text{ kJ}}{1 \text{ mol}} \\
 &= 4.44 \times 10^4 \text{ kJ} \\
 &= 44.4 \text{ MJ}
 \end{aligned}$$

The energy produced per kilogram of octane burned is 44.4 MJ.

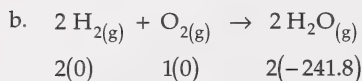
Textbook question 22:



$$\begin{aligned}
 \Delta H_r^\circ &= \sum nH_{fp}^\circ - \sum nH_{fr}^\circ \\
 &= \left(2 \text{ mol} \times \frac{-393.5 \text{ kJ}}{\text{mol}} + 4 \text{ mol} \times \frac{-241.8 \text{ kJ}}{\text{mol}} \right) - \left(2 \text{ mol} \times \frac{-239.1 \text{ kJ}}{\text{mol}} + 3 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) \\
 &= -1276.0 \text{ kJ}
 \end{aligned}$$

$$\begin{aligned}
 H_c^\circ &= \frac{\Delta H_c}{n} & \Delta H_c^\circ &= 1000 \text{ g} \times \frac{1 \text{ mol}}{32.05 \text{ g}} \times \frac{638.0 \text{ kJ}}{1 \text{ mol}} \\
 H_c^\circ &= \frac{-1276.0 \text{ kJ}}{2 \text{ mol}} & &= 19.9 \times 10^3 \text{ kJ} \\
 &= -638.0 \text{ kJ/mol} & &= 19.9 \text{ MJ}
 \end{aligned}$$

The energy produced per kilogram of methanol is 19.9 MJ.



$$\begin{aligned}
 \Delta H_c^\circ &= \sum nH_{fp}^\circ - \sum nH_{fr}^\circ \\
 &= \left(2 \text{ mol} \times \frac{-241.8 \text{ kJ}}{\text{mol}} \right) - \left(2 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} + 1 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) \\
 &= -483.6 \text{ kJ}
 \end{aligned}$$

$$\begin{aligned}
 H_c^\circ &= \frac{\Delta H_c}{n} & \Delta H_c^\circ &= 1000 \text{ g} \times \frac{1 \text{ mol}}{2.02 \text{ g}} \times \frac{241.8 \text{ kJ}}{1 \text{ mol}} \\
 H_c^\circ &= \frac{-483.6 \text{ kJ}}{2 \text{ mol}} & &= 1.20 \times 10^5 \text{ kJ} \\
 &= -241.8 \text{ kJ/mol} & &= 120 \text{ MJ}
 \end{aligned}$$

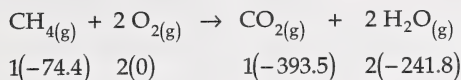
The energy produced per kilogram of hydrogen is 120 MJ.

- c. Hydrogen has a higher energy content (120 MJ/kg) and methanol has a lower energy content (19.9 MJ/kg) per kilogram of the fuel used as compared to octane (44.4 MJ/kg).
- d. Some other factors to consider are as follows:

- Technological perspective – How complicated and safe is the technology required to produce and utilize these different fuels?
- Ecological perspective – What is the effect of the processing and combustion of each of these fuels on the environment?
- Economic perspective – How much will it cost for the conversion to these fuel systems and the maintenance of these systems?

Textbook question 23:

- a. **Step 1** Calculate the enthalpy change of combustion.



$$\begin{aligned} \Delta H_c^\circ &= \sum nH_{fp}^\circ - \sum nH_{fr}^\circ \\ &= \left(1 \text{ mol} \times \frac{-393.5 \text{ kJ}}{\text{mol}} + 2 \text{ mol} \times \frac{-241.8 \text{ kJ}}{\text{mol}} \right) - \left(1 \text{ mol} \times \frac{-74.4 \text{ kJ}}{\text{mol}} + 2 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) \\ &= -802.7 \text{ kJ} \end{aligned}$$

- Step 2** Calculate the molar enthalpy of combustion.

$$\begin{aligned} H_c^\circ &= \frac{\Delta H_c^\circ}{n} \\ &= \frac{-802.7 \text{ kJ}}{1 \text{ mol}} \\ &= -802.7 \text{ kJ/mol} \end{aligned}$$

- Step 3** Using calorimetry techniques, calculate the amount (moles) of methane.

$$\begin{aligned} \Delta H_c &= q \\ \text{(methane)} \quad \text{(water)} \\ nH_c &= mc\Delta t \\ n \times \frac{802.7 \text{ kJ}}{\text{mol}} &= 100 \text{ kg} \times \frac{4.19 \text{ kJ}}{\text{kg} \cdot ^\circ\text{C}} \times (70 - 5)^\circ\text{C} \\ n &= 34 \text{ mol} \\ &= 3 \times 10^1 \text{ mol} \end{aligned}$$

The amount of methane undergoing combustion is 3×10^1 mol.

- b. You can heat water more efficiently by
- modifying the water heater design to maximize use of heat energy produced
 - increasing the insulation around the heating pipes and water pipes
 - heating water that is partially preheated
- c. Solar energy can be used to preheat the water.

Textbook question 24:

$$\begin{aligned}
 H_r &= \frac{\Delta H_r}{n} \\
 &= \frac{1.9 \times 10^{10} \text{ kJ}}{1 \text{ mol}} \\
 &= 1.9 \times 10^{10} \text{ kJ/mol}
 \end{aligned}$$

$$\begin{aligned}
 \Delta H_r &= nH_r \\
 &= 4.26 \text{ mol} \times \frac{1.9 \times 10^{10} \text{ kJ}}{1 \text{ mol}} \\
 &= 8.1 \times 10^{10} \text{ kJ}
 \end{aligned}$$

The amount of energy that can be obtained is 8.1×10^{10} kJ.

Section 3: Activity 3

Note: The answers for questions 1-4 are only samples. Your answers may vary.

1. a. Risky often means that there is some danger of injury or death when participating in a particular activity.
- b. The risk could be measured by the number of injuries or deaths associated with a particular activity per the number of overall participants.
- c. All activities have some degree of risk. Even laying in bed all the time poses a risk against a healthy, toned body.
- d. Keep in mind that the following is just one sample answer.

- Using electrical appliances around the home (7)
- Eating (9)
- Bicycling (6)
- Smoking (3)
- Taking a bus trip (4)
- Playing hockey (5)
- Driving a motorcycle (1)
- Swimming (8)
- Driving a car (2)

2. a. The teacher suggested that risks be compared by the number of deaths resulting from the activities. This comparison is less than complete because it does not take into account the number of people involved in the activity, and other factors such as crippling injuries, degree of participation, and the ages of participating group members.
- b. The risks were compared by using the number of deaths per year in Canada.
- c. The students tended to misjudge the risks because they based their estimates on dramatic events they recalled from their past experiences.
- d. People's perceptions of risk, and the degree of emotional impact that a particular risk has, sometimes override best estimates or statistics.
- e. The risk equation is as follows:

$$\text{Risk} = \text{probability of occurrence} \times \text{consequences}$$

- f. Besides the risks involved, the benefits should be considered as well.
 - g. i. The three major steps are as follows:
 - recognition of the risks and benefits
 - measurement or estimation of their effects
 - comparisons with other ways of doing things
 - ii. This method is called risk/benefit analysis.
3. Consider the last statistic about smoking.

Step 1

Calculate the time that life is shortened.

$$t = 3.5 \text{ y} \times \frac{365.25 \text{ d}}{1 \text{ y}} \times \frac{24 \text{ h}}{1 \text{ d}} \times \frac{60 \text{ min}}{1 \text{ h}}$$
$$= 1.841 \times 10^6 \text{ min}$$

Step 2

Calculate the number of cigarettes smoked.

$$\# = 50 \text{ y} \times \frac{365.25 \text{ d}}{1 \text{ y}} \times \frac{1 \text{ pack}}{1 \text{ d}} \times \frac{25 \text{ cigarettes}}{1 \text{ pack}}$$
$$= 4.566 \times 10^5 \text{ cigarettes}$$

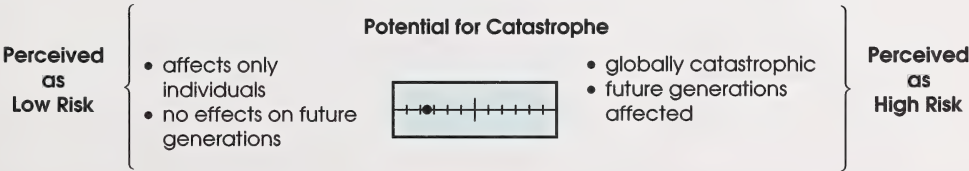
Step 3

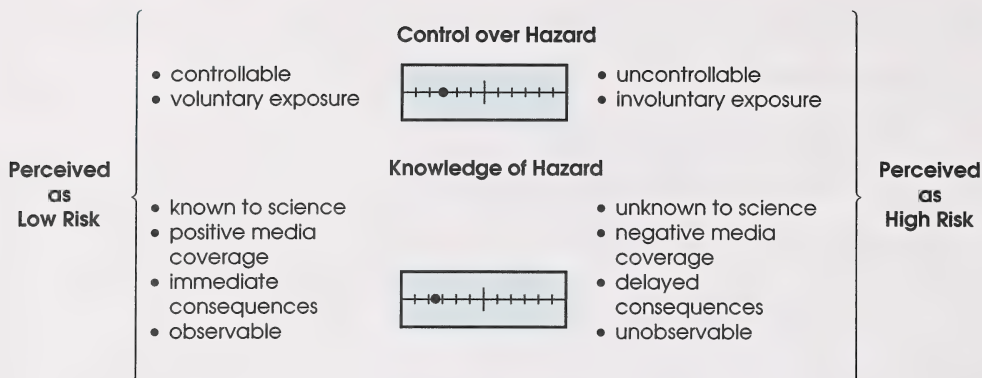
Calculate the number of minutes per cigarette.

$$\frac{1.841 \times 10^6 \text{ min}}{4.566 \times 10^5 \text{ cigarettes}} = \frac{4.0 \text{ min}}{\text{cigarette}} \quad (\text{Note: This value is fairly close to the first statistic given.})$$

People shorten their life by 4.0 min per cigarette when they smoke.

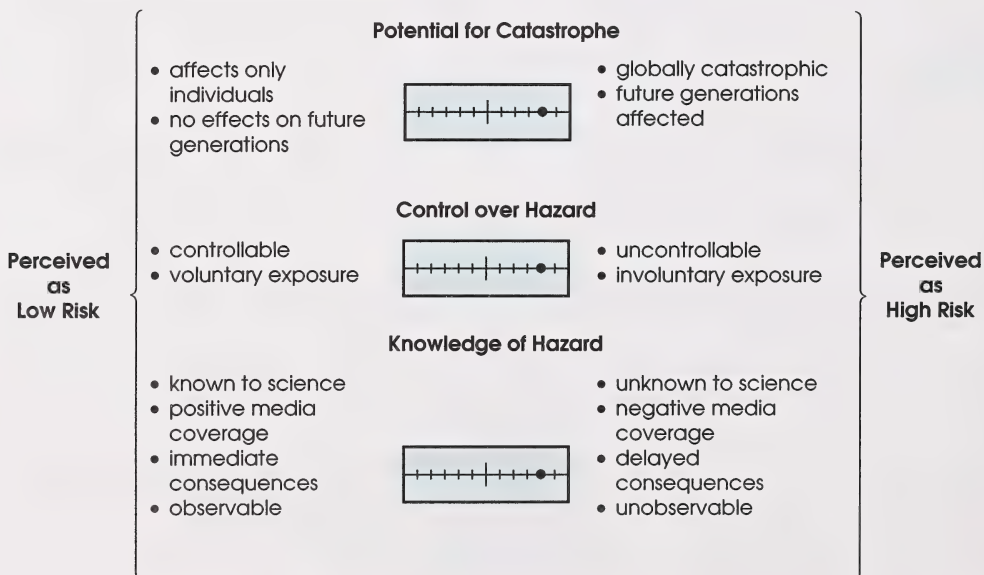
4. The response would likely be indifference. The numbers would likely not mean very much because they are so small. More statistics would likely not help since the numbers are so small.
5. There are no right or wrong answers to this question. A typical answer is shown. Be sure to check that your explanation is consistent with your rating on the continuum.





Using the continuum and the trends mentioned earlier, most people would probably rate the potential for a catastrophe as being low in this case. Unless you live in a valley below a hydroelectric dam, it is unlikely that you would perceive the stations as having the potential to kill many people. The same thinking applies to the control over the hazard. Unless you live in a valley below a hydroelectric dam, the hazard should be perceived by most people as being controllable. The non-nuclear generating stations use known, conventional technology, so the perceived risk should be low on this factor as well. Overall, most people would perceive non-nuclear electric power as a low risk.

6. As with the previous question, there are no right or wrong answers. A typical answer is shown. Be sure that your explanation is consistent with your rating on the continuum.



The given response would likely reflect how most citizens would perceive the risk from nuclear power. Many people would describe a nuclear accident as being potentially catastrophic, affecting thousands of people indiscriminately with invisible, mysterious radiation and radioactive fallout. A very high perceived risk would exist in the minds of most people.

7. Many possible suggestions could be mentioned. The following list represents some of these possibilities.
 - Members of the general public may need to learn more about issues so that they can check their perceptions against the risk assessments of the experts.
 - Scientific experts need to explain the nature of risk in clear, understandable language.
 - The general public and experts need to communicate with each other and become more like partners looking for solutions and less like adversaries trying to prove who's right.
8. The director of the Environment Centre of Alberta was very concerned about the possibility of a Chernobyl-type accident and about the potential for nuclear wastes being released into the environment.
9. The spokesman for Saskatchewan Power claimed that all sources of generating electric power have a potential impact on the environment.
10. The physics professor explains that Saskatchewan uses lignite coal in its coal-fired power plants. This type of coal is particularly bad for emitting carbon dioxide when it is burned. Carbon dioxide is a greenhouse gas that contributes to global warming. The physics professor thinks that global warming presents a much greater risk to future generations than nuclear waste does.
11. If Alberta's coal-fired plants were converted to natural gas, the amount of carbon dioxide released would be reduced because natural gas (methane) releases less carbon dioxide than coal. The Energy Minister disagrees with a move to natural gas because he claims that the pollution problem in Alberta isn't nearly as bad as in other places that switched from coal to natural gas, such as California. The Energy Minister says that Alberta's environmental standards for industry are among the strictest in North America.
12. The Alberta Environment Minister recommends that the three prairie provinces use coal and hydroelectric power.
13. The University of Calgary physics professor maintains that global warming is a greater risk than the wastes from a nuclear power plant. Burning coal contributes to the levels of atmospheric carbon dioxide and to global warming.

The Alberta Environment Minister recommends that coal be used in addition to hydroelectric power for the three prairie provinces. He considers the potential for accidents and the problems of waste disposal major concerns.

14. a. The overall advantages of generating electricity from nuclear power are as follows:
 - Nuclear energy does not depend on resources that will be depleted in the coming decades – uranium is a very concentrated energy source.
 - Nuclear power is an inexpensive fuel source.
 - Nuclear power does not contribute to smog, acid rain, or global warming.
 - Nuclear power is safe in terms of being strictly regulated.

- b. The disadvantages of using nuclear power for generating electricity are as follows:
- There is a possible risk of release of radioactive materials.
 - There is difficulty in disposing of highly toxic radioactive waste.
 - Nuclear reactors cost a large amount of money to build and to take down.
 - Nuclear reactors have a short lifetime.
 - There is a risk that nuclear weapons will be made from the plutonium product of the nuclear reaction.
- c. The final evaluation states that increased nuclear power may be needed to meet the increased energy needs and environmental demands of society, but this increase appears unlikely at present given the number of disadvantages and negative public opinion.
15. A nuclear reactor could help to generate steam that is needed to extract heavy oil from tar sands.
16. The previous Saskatchewan government was replaced by a new party that was not in favour of generating electricity from nuclear power.
17. The professor claims that CANDU reactors are among the safest in the world, with the potential of a Chernobyl-type accident being an impossibility.
18. The following essays represent some of the possible approaches to this question. It should be noted that it is not the particular opinion (A or B) that matters, but rather how the opinion is supported in terms of the criteria stated in the question.

- Opinion A

A nuclear generating station should not be considered as a way to generate electricity in Alberta in the next twenty years. Alberta's current inventory of fossil fuels makes this unwise and energy conservation should be considered first to prevent the building of any new generating stations – including nuclear ones.

Alberta has about 60 percent of Canada's proven coal reserves, not to mention a healthy quantity of oil and natural gas. These energy sources are relatively inexpensive, are accessible, and they help employ Albertans. The fuel for a nuclear generating station is not available in Alberta and would not add as much to this province's economy.

Alberta is already an energy-rich province. The best use of all its resources is to use them wisely through conservation practices. The idea of building a nuclear generating station implies that more electricity is needed, when really society should be cutting back to prevent further depletion of natural resources and damage to the environment.

In conclusion, the author of the editorial in the *Edmonton Journal* said it best – “Trying to interest Alberta in a nuclear industry seems a bit like trying to persuade Florida to import grapefruits.”

- Opinion B

Nuclear generating stations are a safe and responsible way to generate electricity. Alberta should grow out of its dependency on fossil fuels and embrace nuclear energy as a way to generate electricity. Nuclear energy is better for the environment and it is the fuel of the future.

The conventional way to generate electricity is to use fossil fuels. When these fuels are burned, they release carbon dioxide and other substances into the environment. These substances create long-term problems.

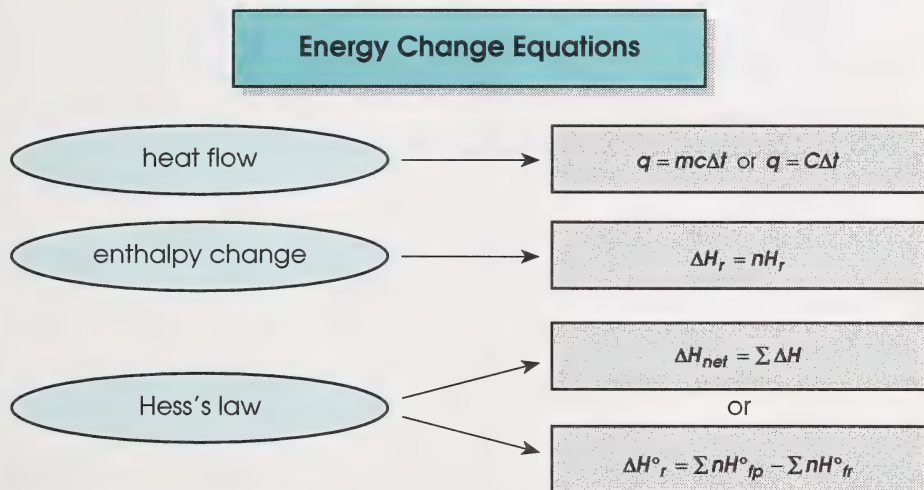
Carbon dioxide is a greenhouse gas, which contributes to the problems of global warming. Many people, including Harvey Buckmaster, a physics professor from the University of Calgary, would argue that global warming poses more of a threat to future generations than do the problems associated with nuclear power.

Other environmental problems created by the burning of fossil fuels are acid rain and smog. Prolonged use of fossil fuels in eastern North America and Northern Europe has created major problems for fish and other organisms in delicate ecosystems.

Fossil fuels will not be around forever and society needs the planet to stay healthy. If this is the case, Alberta should begin to reduce its economic dependency on fossil fuels to prepare for the future. Nuclear power does not contribute to smog, acid rain, or global warming, and is a better option for the environment.

Section 3: Activity 4

1.



Note: You haven't been using the volumetric heat flow equation, $q = vc\Delta t$, so it was not included here.

2. The combination of equations is:

Step 1

$$\Delta H^\circ_r = \sum nH^\circ_{fp} - \sum nH^\circ_{fr}$$

Step 2

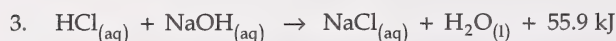
$$H^\circ_r = \frac{\Delta H^\circ_r}{n}$$

Step 3

$$n = \Delta H^\circ_r \times \frac{1}{H^\circ_r}$$

Step 4

$$\text{mass} = \text{moles} \times \text{molar mass}$$



Step 1

Calculate the molar enthalpy.

$$\begin{aligned} H_r &= \frac{\Delta H_r}{n} \\ &= \frac{55.9 \text{ kJ}}{1 \text{ mol}} \\ &= 55.9 \text{ kJ/mol} \end{aligned}$$

Step 2

Calculate the volume required.

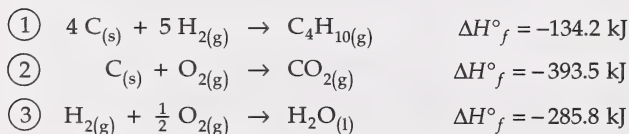
$$\begin{aligned} v_{(\text{HCl})} &= 95.0 \text{ kJ} \times \frac{1 \text{ mol HCl}}{55.9 \text{ kJ}} \times \frac{1 \text{ L}}{0.200 \text{ mol HCl}} \\ &= 8.50 \text{ L} \end{aligned}$$

The volume required is 8.50 L.

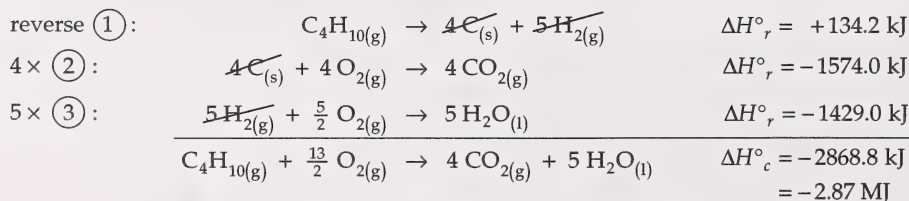
4. a. Calorimetry Methods

$$\begin{aligned} \Delta H_c &= q \\ (\text{C}_4\text{H}_{10}) \quad (\text{calorimeter}) \\ nH_c &= C\Delta t \\ 1.52 \text{ g} \times \frac{1 \text{ mol}}{58.14 \text{ g}} \times H_c &= \frac{9.35 \text{ kJ}}{^\circ\text{C}} \times (28.25 - 20.21)^\circ\text{C} \\ H_c &= 2875.4 \text{ kJ/mol} \\ &= 2.88 \text{ MJ/mol} \quad \text{The molar enthalpy is } -2.88 \text{ MJ/mol.} \end{aligned}$$

Hess's Law – Formation Reactions



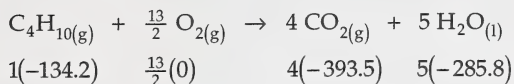
Rearrange the equations:



$$\begin{aligned}
 H_c^\circ &= \frac{\Delta H_c^\circ}{n} \\
 &= \frac{-2.87 \text{ MJ}}{1 \text{ mol}} \\
 &= -2.87 \text{ MJ/mol}
 \end{aligned}$$

The molar enthalpy is -2.87 MJ/mol .

Enthalpies of Formation – Products Minus Reactants



$$\begin{aligned}
 \Delta H_c^\circ &= \sum nH_{fp}^\circ - \sum nH_{fr}^\circ \\
 &= \left(4 \text{ mol} \times \frac{-393.5 \text{ kJ}}{\text{mol}} + 5 \times \frac{-285.8 \text{ kJ}}{\text{mol}} \right) - \left(1 \text{ mol} \times \frac{-134.2 \text{ kJ}}{\text{mol}} + \frac{13}{2} \text{ mol} \times 0 \frac{\text{kJ}}{\text{mol}} \right) \\
 &= -2868.8 \text{ kJ}
 \end{aligned}$$

$$\begin{aligned}
 H_c^\circ &= \frac{\Delta H_c^\circ}{n} \\
 &= \frac{-2868.8 \text{ kJ}}{1 \text{ mol}} \\
 &= -2868.8 \text{ kJ/mol} \\
 &= -2.87 \text{ MJ/mol} \quad \text{The molar enthalpy is } -2.87 \text{ MJ/mol.}
 \end{aligned}$$

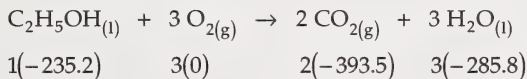
- b. An evaluation of the methods used can be made using Hess' law (predicted) and calorimetry (experimental) values:

$$\begin{aligned}
 \% \text{ error} &= \frac{\left| 2.8754 \text{ MJ/mol} - 2.8688 \text{ MJ/mol} \right|}{\left| 2.8688 \text{ MJ/mol} \right|} \times 100\% \\
 &= 0.2\%
 \end{aligned}$$

The reliable method of calorimetry and the Hess's law methods show good agreement, which instills confidence in the methods.

5.

Step 1



$$\begin{aligned}
 \Delta H_c^\circ &= \sum nH_{fp}^\circ - \sum nH_{fr}^\circ \\
 &= \left(2 \text{ mol} \times \frac{-393.5 \text{ kJ}}{\text{mol}} + 3 \text{ mol} \times \frac{-285.8 \text{ kJ}}{\text{mol}} \right) - \left(1 \text{ mol} \times \frac{-235.2 \text{ kJ}}{\text{mol}} + 3 \text{ mol} \times \frac{0 \text{ kJ}}{\text{mol}} \right) \\
 &= -1409.2 \text{ kJ}
 \end{aligned}$$

Step 2

$$\begin{aligned}
 H_c^\circ &= \frac{\Delta H_c^\circ}{n} \\
 &= \frac{-1409.2 \text{ kJ}}{1 \text{ mol}} \\
 &= -1409.2 \text{ kJ/mol}
 \end{aligned}$$

Step 3

$$\begin{aligned}
 \Delta H_c &= q \\
 &= (\text{ethanol}) \left(\frac{\text{calorimeter}}{\text{water}} \right) \\
 nH_c &= mc\Delta t \\
 1.50 \text{ g} \times \frac{1 \text{ mol}}{46.08 \text{ g}} \times \frac{1409.2 \text{ kJ}}{\text{mol}} &= 0.200 \text{ kg} \times \frac{4.19 \text{ kJ}}{\text{kg} \cdot ^\circ\text{C}} \times \Delta t \\
 \Delta t &= 54.7^\circ\text{C}
 \end{aligned}$$

Step 4

$$\begin{aligned}
 \Delta t &= t_f - t_i \\
 t_f &= \Delta t + t_i \\
 t_f &= 54.7^\circ\text{C} + 25.0^\circ\text{C} \\
 &= 79.7^\circ\text{C}
 \end{aligned}$$

The final temperature is 79.7°C .

6.

Step 1



$$\begin{aligned}
 H_c &= \frac{-32.8 \text{ kJ}}{1 \text{ g}} \times \frac{12.01 \text{ g}}{\text{mol}} \\
 &= -393.93 \text{ kJ/mol} \\
 &= -394 \text{ kJ/mol}
 \end{aligned}$$

Step 2

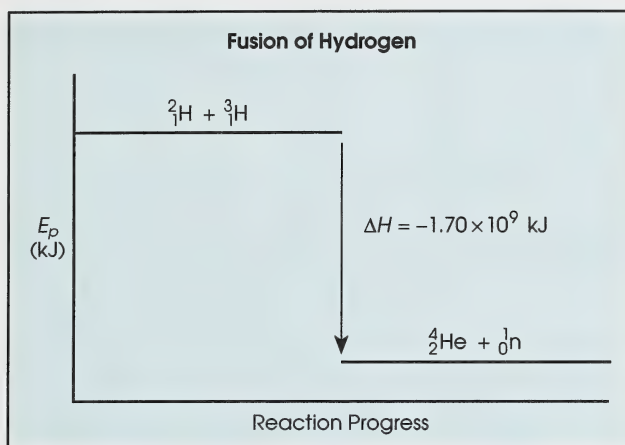
$$\begin{aligned}
 \Delta H_r &= q \\
 &= (\text{coke}) \left(\frac{\text{calorimeter}}{\text{water}} \right) \\
 nH_r &= mc\Delta t \\
 m \times \frac{1 \text{ mol}}{12.01 \text{ g}} \times \frac{393.93 \text{ kJ}}{\text{mol}} &= 2.00 \text{ kg} \times \frac{4.19 \text{ kJ}}{\text{kg} \cdot ^\circ\text{C}} \times (95.0 - 25.0)^\circ\text{C} \\
 m &= \frac{586.6 \text{ kJ} \cdot \text{g}}{32.800 \text{ kJ}} \\
 &= 17.9 \text{ g}
 \end{aligned}$$

The required mass of coke is 17.9 g.

Section 3: Follow-up Activities

Extra Help

1. Alternatives **a**, **c**, and **d** are nuclear because they involve a change in the arrangement of nuclear particles from the reactants to the products.
2. The potential energy diagram is as follows:



3. **Step 1** Calculate molar enthalpy of reaction for $^{92}_{36}\text{Kr}$.

$$\begin{aligned}
 H_r &= \frac{\Delta H_r}{n} \\
 &= \frac{-1.9 \times 10^{10} \text{ kJ}}{1 \text{ mol}} \\
 &= -1.9 \times 10^{10} \text{ kJ/mol}
 \end{aligned}$$

Step 2

Calculate the mass of $^{92}_{36}\text{Kr}$ produced. The molar mass for $^{92}_{36}\text{Kr}$ is 92 g/mol (from the mass number).

$$\begin{aligned}
 m_{(\text{Kr})} &= 2.6 \times 10^9 \text{ kJ} \times \frac{1 \text{ mol}}{1.9 \times 10^{10} \text{ kJ}} \times \frac{92 \text{ g}}{1 \text{ mol}} \\
 &= 12.59 \text{ g} \\
 &= 13 \text{ g}
 \end{aligned}$$

The mass of $^{92}_{36}\text{Kr}$ produced is 13 g.

4. a.

COMPARING RISK ASSESSMENT TO RISK PERCEPTION		
	Risk Assessment	Risk Perception
Who does it?	experts	general public
What strategies are used?	Probability and statistics are used to carefully analyse available data. In many steps of the procedures, estimates have to be made, which make risk assessment an inexact science.	Studies have demonstrated that lay people tend to employ three basic criteria when determining risks: • potential for catastrophe • degree of control over the hazard • knowledge of the hazard
What is the outcome of this process?	a probability with an associated uncertainty	an opinion in the mind of the observer

b. Experts and the general public employ very different strategies in analysing risks, so the outcomes are often different. While the expert may focus only on things that can be measured or counted, the general public has a much broader notion of risk that encompasses considerations that may be overlooked by the expert.

5. a. $nH_c = q$

d. no formula equation

b. $H_c = \frac{\Delta H_c}{n}$

e. $\Delta H_c = \sum nH^\circ_{fp} - \sum nH^\circ_{fr}$

c. $q = mc\Delta t$

The statements, with their equations, in the correct sequence are c, a, d, e, b. (The order could also be d, c, a, e, b.)

Enrichment

1. One sample form is given here. Unless indicated differently, for each question, the left side of the continuum represents a low risk and the right represents a high risk perception.

Potential for catastrophe	
Effect on individuals	Low High
Global effect	
Does it affect future generations?	
Number of catastrophes which you think have occurred in the past three decades.	
What is the probability of a catastrophe occurring?	
Control over hazard	
To what degree can it be controlled?	
Do you think nuclear waste can be disposed of safely?	
Can exposure to radiation be controlled?	
Knowledge of hazard	
Are the consequences of the hazard known to science?	Yes No
Are the effects of the hazard observable?	Observable Unobservable

2. One approach is given as follows.

Reasons in support of the hydrogen-powered car are

- It is environmentally friendly; it does not contribute to acid rain.
- Its fuel is completely renewable, because water can be decomposed to produce hydrogen.
- It does not contribute to the greenhouse effect because carbon dioxide or other greenhouse gases are not produced.
- It gives more energy per unit mass of the fuel relative to gasoline.

3. The comparison of different fuels is as follows.

Energy Released (kJ/g)	Advantages	Disadvantages
Methanol 19.9	• stalls greenhouse effect • environmentally friendly relative to gasoline	• not completely renewable
Ethanol 27.7	• same as methanol • completely renewable	• expensive to produce • production depends on sugars from plants
Hydrogen 119.7	• environmentally friendly • renewable source • does not contribute to global warming	• expensive to produce • difficult to transport
Octane 44.5	• relatively cheap to produce • abundant supplies • liquid; easy to transport	• contributes to pollution • responsible for global warming • fossil fuel; non-renewable
Natural gas 50.0	• abundant supplies • less pollution relative to coal	• same as octane
Coal 32.8	• cheap to produce in places where supplies are abundant	• same as octane

Article Readings for Section 3: Activity 3

Reactor Proposal Draws Ire

By KEVIN BLEVINS
Journal Staff Writer

Albertans may have a nuclear power plant on their doorstep – if Saskatchewan goes ahead with plans for building a Candu-three reactor.

A spokesman for SaskPower, Saskatchewan's public electricity utility, said Tuesday if a reactor is built – a first for Western Canada – it would probably be located in the northwest part of Saskatchewan.

It might even end up close to the Alberta border, he suggested.

But Brian Staszewski, director of the Environment Centre of Alberta, promises to fight the proposal, calling it a "step backwards."

"In Western Canada, with all our power resources, the last thing we need is a nuclear reactor," he said.

Albertans should be alarmed by the possibility of a nuclear power plant next door, he said, raising the

possibility of a disaster like a meltdown or a release of nuclear wastes into the environment. Locating it near Lloydminster, which straddles the border between the two provinces and is the site of the \$1.3-billion Husky heavy-oil upgrader, would be disturbing.

"So if they try to do this, I think they will see one of the biggest fights they've ever seen," he said.

Bob Rempel, spokesman for SaskPower in Regina, acknowledged environmental concerns about nuclear power, but said any type of power source affects the environment.

"With hydroelectricity, you have the change of habitat, the effects on wildlife. With coal-fired plants, there are the arguments about the greenhouse effect and acid-rain . . . But when you look at what's been done in Ontario, I think nuclear power has come a long way."

Ontario, New Brunswick and Quebec are the only Canadian provinces with nuclear power plants.

Saskatchewan has coal-fired plants in the southeast, hydroelectric plants in the northeast and southwest, but there isn't a major power plant in the northwest, Rempel said.

"No one's looking at any specific spot. We're not that far yet. But the northwest, north-central part of the province would certainly be high on the list."

An even greater factor in determining the reactor's

location may be the Husky upgrader in Lloydminster, slated to begin operation in 1992.

It would be logical and economical to build a new power plant near a large industrial consumer like the upgrader, which will use electricity equivalent to that of a city of 30,000, Rempel said.

Greg Barnes, the manager of engineering for the upgrader, said the reliable source of electricity a nuclear reactor would provide is welcomed.¹

Nuclear Reactor Option Defended

By KEVIN BLEVINS
Journal Staff Writer

A University of Calgary physics professor says Albertans shouldn't be too alarmed by the possibility of having a nuclear reactor next door, in Saskatchewan.

"In the next 30 years, the problems of carbon dioxide and its effects on the atmosphere are, in my opinion, (going to be) far greater than those of nuclear waste," Harvey Buckmaster said Wednesday.

Buckmaster was referring to worldwide concerns that too much carbon dioxide in the atmosphere is warming the earth's climate to dangerously high levels.

Carbon dioxide is released when coal is burned. Buckmaster has been studying the effects of carbon dioxide on the atmosphere for the last 10 years.

The latest available statistics from the United Nations show that Canada produced the fourth highest amount of carbon dioxide per capita in the world in 1986, Buckmaster said.

SaskPower, Saskatchewan's public electricity utility, is considering participating in a plan to buy power from a privately owned, Candu-three reactor, which would be built in Saskatchewan.

SaskPower officials have suggested that if the reactor is built, it would probably be in the northwestern part of the province, possibly near the Alberta border.

That worries the Environment Centre of Alberta and the provincial government.

But Buckmaster says the nuclear option is not a bad one because Saskatchewan uses lignite coal for its coal-fired plants – a coal that emits the most carbon dioxide when burned.

"If you closed down the Estevan coal-fired plant (Boundary Dam) in Saskatchewan, and replaced it with a nuclear one, you'd probably be making an environmental advancement," he contended.

"Anti-nuclear activists often forget that the Candu reactors are by far the safest in the world. With their technology, a Chernobyl is an impossibility."

The world's worst nuclear accident occurred in 1986 when the Chernobyl plant exploded in the Soviet Union, killing 31 people and causing acute radiation sickness in 237 others.

In Alberta, with its vast coal and natural gas resources, nuclear energy isn't needed, Buckmaster says.

But he would like to see existing coal-fired plants converted to natural gas because the carbon dioxide emitted from methane is significantly less than that emitted from coal.

However, Energy Minister Neil Webber says any such conversion is unlikely.

"I know they are converting coal-generation plants to natural gas in California, but when you look at pollution in Los Angeles and Alberta, there's no comparison," he said. "We don't have that kind of pollution problem."

In general, Alberta's environmental standards for industry are among the strictest in North America, he added.²

¹ The Edmonton Journal for the article, "Reactor Proposal Draws Ire," by Kevin Blevins, taken from February 8, 1989, p. B1. Reprinted with permission of The Edmonton Journal.

² The Edmonton Journal for the article, "Nuclear Reactor Option Defended," by Kevin Blevins, taken from February 9, 1989, p. A18. Reprinted with permission of The Edmonton Journal.

Alberta Wary of Saskatchewan Nuclear Project

By **ED STRUZIK and KEVIN BLEVINS**
Journal Staff Writers

Alberta doesn't want a nuclear power plant near the Saskatchewan border, nor anywhere else in that province, says Environment Minister Ian Reid.

Reid was commenting Wednesday on a plan by SaskPower to buy power from a privately owned nuclear-power plant that is being proposed for the northwest part of the province or possibly around Lloydminster.

"I'm not at all sure that it's necessary to be considering atomic generation in western Canada at any location," Reid said.

"We may have uranium mines, but we have a large amount of coal and there is still the potential for electric power in northern Manitoba, maybe even in the Slave River in Alberta," he said.

In fact, said Transportation and Utilities Minister Al Adair, nuclear power in Alberta is "not even an option."

Reid said Saskatchewan wouldn't necessarily have to consult with Alberta about building the reactor because it's a matter of federal jurisdiction.

But the potential for radioactive accidents, and the problems of disposing of nuclear waste safely are still major concerns, Adair said Wednesday.

Adair said the provincial government will continue to support the use of coal-fired plants as Alberta's main generator of electricity.

A spokesman for SaskPower, Saskatchewan's public electrical utility, said Tuesday an approval in principle has been reached between SaskPower and a private company to build a nuclear power plant in Saskatchewan, possibly near the Alberta border.

Bob Rempel, a spokesman for SaskPower, confirmed Tuesday that a plan has been approved in principle to allow a 450-megawatt, Candu-three reactor to be built by Atomic Energy of Canada Ltd., and owned by Western Project Development Associates.¹

Use of Nuclear Reactors to Extract Heavy Oil Studied

RICK PEDERSEN
Journal Staff Writer

Edmonton

Nuclear reactors will be used in the Alberta oilpatch eventually as non-renewable fuels like natural gas begin to deplete, says the chairman of the Alberta Oil Sands Technology and Research Authority.

The only question is when, Bill Yurko said Monday.

The authority has joined Atomic Energy of Canada in a study to determine if a CANDU-3 nuclear reactor could produce steam for extracting heavy oil and bitumen.

"We're each putting in \$125,000."

The study will be completed in March 1994, he said, explaining that the project was unveiled recently

to the House of Commons energy committee.

This is the second time around for the idea.

"We did this study 11 years ago," Yurko said, and although nuclear power was a competitive alternative in the early 1980s natural gas is still used instead.

The earlier study needs updating now, Yurko said.

High-pressure steam was required when the first study was done, but now new technologies mean low-pressure steam can do the job. This makes a nuclear reactor more suitable, he said.

But the price of natural gas has dropped sharply making this fuel even more competitive.

Once the study is complete the politicians will have to decide what to do, he said.²

¹ The *Edmonton Journal* for the article, "Alberta Wary of Saskatchewan Nuclear Project," by Ed Struzik and Kevin Blevins, taken from February 9, 1989, p. B1. Reprinted with permission of *The Edmonton Journal*.

² The *Edmonton Journal* for the article, "Use of Nuclear Reactors to Extract Heavy Oil Studied," by Rick Pedersen, taken from March 24, 1992, p. A8. Reprinted with permission of *The Edmonton Journal*.

A Nuclear Alberta?

On the face of it, trying to interest Alberta in a nuclear industry seems a bit like trying to persuade Florida to import grapefruits. When it comes to energy, Alberta is in a surplus position.

There are also the questions of environmental and human safety that continue to surround the nuclear industry. Atomic Energy of Canada Ltd., the Crown corporation that builds and markets Candu reactors, has insisted for decades that its reactors are as safe as any in the world, if not safer, but large segments of the population remain unconvinced.

Three Mile Island, Chernobyl and a number of lesser nuclear accidents have left their impact on the public mind. Just this week, while AECL was promoting its nuclear plans to Alberta, Russian scientists were contending with a radioactive leak at a plant near St. Petersburg – different make of plant, of course, but a nuclear plant. Does Alberta, so rich in other energy sources, need this aggravation?

AECL, of course, badly needs the business. For all the federal investment in research over the years, and the worldwide marketing, the federal corporation has not managed many foreign sales. With Ottawa scaling back its funding, AECL has turned determinedly to the provinces for support. Here, too, it has had mixed success. Ontario Hydro largely runs its own nuclear show. The former Saskatchewan government of Grant Devine agreed to a research and development program with AECL, but the province's new NDP government has let the agreement lapse. Which now brings AECL to Alberta.

The AECL offer to Alberta is apparently similar to the one made to Saskatchewan – a research program aimed at the building of Candu 3 reactors. There is a special wrinkle in Alberta because of the potential for using a Candu reactor to supply the steam for

extracting oil from the province's oil sands – a mixing of energy technologies, in other words.

You can entertain the suspicion that AECL is happy to play one province against the other in hopes of forcing a deal. If that is the case, it is having some success – in Saskatchewan at least. Having let Saskatchewan's agreement lapse, NDP Premier Roy Romanow is now doing a bit of backpedalling. Saskatchewan, he suggests, would be happy to sign a research deal so long as it doesn't involve actual reactor construction. Alberta could take that. It is hard to imagine a worse form of provincial – truly provincial – competition.

Alberta, quite rightly, is reacting with some skepticism. This is a province with a 50-year supply of natural gas and a 200-year supply of coal, both of which are in direct competition with nuclear power as energy sources. Natural gas at present has advantages of being inexpensive and of being perceived to be safer than nuclear power. This is not a ripe market, in other words, for nuclear power. Energy Minister Rick Orman says he has conveyed as much to AECL salespeople.

There remains the question of nuclear technology in the oil sands. An Alberta agency is helping to fund a feasibility study, and has looked at the question off and on for the past decade. Research is always valuable – so long as this research doesn't become the means for introducing a nuclear energy without the prior say of the people of Alberta.

Given the enduring question of safety, and Alberta's wealth of other energy sources, the province should not consider nuclear energy before it has openly consulted the people. Research programs should be fully disclosed. And we should keep in mind that it will be decades before the gas runs out.¹

¹ The *Edmonton Journal* for the editorial, "A Nuclear Alberta," taken from March 25, 1992, p. A10. Reprinted with permission of The *Edmonton Journal*.



